RICE IN MADRAS

A

POPULAR HANDBOOK

BY

K. RAMIAH

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PREFACE

THE book is the outcome of a demand for a popular and non-technical publication bringing together all the available knowledge about rice-growing in different parts of the Madras Presidency. Due to the importance of the rice crop to the Province, work on it, particularly on the agronomic side has been conducted from the very early days of the department in several of the older agricultural stations, Coimbatore, Manganallur, Palur, Samalkota, etc. Regular breeding work was, however, initiated only in 1914, with the opening of a Paddy Breeding Station in Coimbatore under the control of the Government Economic Botanist, whose designation was later changed as the Paddy Specialist. The development of the work at the paddy station led to the opening of a number of sub-stations for rice work at Aduturai, Maruteru, Pattambi and Berhampur, to tackle problems of particular important rice tracts. Each of these stations, in addition to selection work in the local varieties of rice, has been carrying on intensive research on the agronomic problems of the tract. While the results of the various experiments in the agricultural stations dealing with rice have been published in the several annual station reports, the attempt has been to bring together all the information in a book form in the present publication. In dealing with experiments, tabular statements of data have been purposely avoided and only the summary of results obtained is given. While the book cannot, by any means, be considered a text-book on rice, it is presumed it will be found useful by the numerous agricultural subordinate officers working in the districts, by the students of the Agricultural College and by a large number of English-knowing public interested in rice cultivation.

Though the publication deals mainly with rice in Madras, for the benefit of the readers, a summary of the rice-growing conditions obtaining outside Madras in India and in

other countries has been included (Chapter XXVII). While the cultivation of the crop has been dealt with in great detail, the portion dealing with rice-breeding is only an elementary treatise, the more technical data bearing on the genetics of the rice plant being reserved for a later scientific publication. In explaining mendelism (Chapter XXI) the author has closely followed the Research Monograph No. 4 of the Ministry of Agriculture and Fisheries in England (Chapter 2) as, in his experience, he has not come across any publication in which the subject has been dealt with in a more simple and lucid way. To make the book somewhat complete, a Chapter (XXIV) on insect and fungus pests of rice in Madras has been included but the material for this chapter has been freely borrowed from the two Madras Departmental Bulletins, Nos. 27 of 1932 and 32 of 1933. The Chapter (XXVI) dealing with seed purity is an abridged form of what was previously written and published by R. O. Ilife when he was Paddy Specialist in Madras. For the discussion of the various manurial experiments with rice in the different experimental stations in Madras (Chapter XI) the author is indebted to S. N. Venkataraman, now Assistant Marketing Officer in the department, who had prepared a report (unpublished) at the instance of the Imperial Council of Agricultural Research.

While the author has freely drawn on the help of all members of the staff in the Paddy Section in the preparation of the book, special mention might be made of assistant K. Hanumantha Rao, who has largely helped the author in the preparation of the index and in proof-reading.

The author's thanks are due to Mr. S. V. Ramamurti, I.C.S., former Director of Agriculture, who gave a stimulus to the writing of the book and to the Superintendent, Government Press, for the promptness with which the publication was put through and for its neat get-up.

K. RAMIAH.

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CHAPTER I

Rice, Origin and Antiquity

Rice (*Oryza sativa*) is one of the earliest of the crops to come under cultivation. It is the main staple food of half the world's population. Almost all the Eastern nations, Japanese, Chinese, Indians, etc., live on it. Rice belongs to the great group of plants comprising the family *Gramineae* in which are included all of our cereals, (wheat, maize, cholam, ragi, etc.), sugarcane, and all fodder grasses. There are several hundreds of varieties in cultivation and it has been stated that there are a few thousands of them in India itself.

Botanical researches point out that every one of our cultivated crop plants must have originated from a primitive wild form existent in very ancient times and the improved forms now under cultivation must have gradually evolved from them by a series of steps. It has been possible to explain in a way how the present cultivated forms of, say, wheat or sugarcane should have been derived, what the wild forms were from which they arose, and the original home from which they should have spread to different parts of the world. Concerning rice such information as is available is still a matter of speculation. But researches point out unmistakably to the fact that South-East Asia, India, China, or Indo-China, must have been the original home of rice. Original homes are characterized by the great diversity of forms, rich in varieties and it is in these three countries that the greatest diversity is to be found. All the Hindu scriptures mention it and all offerings to God are given as rice which denote its antiquity. Some of the very ancient Tamil *puranas* contain descriptions of particular varieties of rice which are to be used in certain religious offerings showing that even in those ancient times varieties with definite grain characteristics were recognized. In an ancient Chinese work it is recorded that the sowing of rice was an important religious ceremonial nearly 5,000 years ago. To the Emperor alone is said to have been reserved the privilege of sowing rice, the less important cereals being left for less exalted members of the family. It is mentioned that rice was one of the five principal plants nourishing the country, being of high economic importance even at that remote epoch. Whether rice was introduced into India

from China or it existed in India at the same time as in China, cannot be accurately determined. Ancient Egyptians did not know about rice nor has this crop been mentioned in the Old Testament. There are records to show that rice was grown in Java as far back as 1084 B.C. It is from India that rice spread to Persia, Mesopotamia and Turkestan. According to Greek authors rice penetrated into Europe only by 300 B.C. introduced by Alexander the Great from India. In the household of the ancient Greeks and Romans, rice was not used, but in the beginning of the present era, as a consequence of commercial intercourse with the East, rice appeared in the Roman markets as a cheap product especially recommended by Greek doctors as a readily digestible food. The introduction of rice into Japan, Philippines and other Pacific Islands must have been from China and Korea.

The cultivation of rice in Europe did not begin until the close of the seventh century. The Arabs when they brought the whole of North Africa under them, introduced it into Egypt and Southern Mediterranean coasts. When they conquered Spain it was taken there. From Spain rice spread to Italy in the sixteenth century when the latter came under Spanish rule. It spread gradually in the Balkans still later.

As regards introduction into America the first attempt was made at the time of the second voyage of Columbus in 1493 but it did not succeed. The attempt however succeeded later when in 1694, a Dutch vessel took some rice there from Madagascar. The spread of rice into South America, Brazil and other republics has been later still, i.e., in the beginning of the eighteenth century.

A Russian Botanist has made a comprehensive survey of the rice species taking into consideration the geographical areas of the different species or groups of species. From the accurate descriptions of these species and their relationship to the cultivated rices, he concludes, that though the question of origin is still far from being solved, the wild rice in its complex forms is the progenitor of the majority of varieties of cultivated rice in India and Indo-China. It is probable that the conditions in India were suitable for the wild progenitor to produce numerous new forms and to give rise to the large number of varieties cultivated at present. Even now, careful observations on a big population of pure varieties, reveal occasionally, new mutations which can be readily fixed and multiplied. There is no doubt that during the long period that rice has been cultivated, natural hybridization has also played a large part in the evolution of varieties. Even now we are familiar, in certain rice tracts like Malabar, with the particular wild rice, *vari nellu*, which appears in the fields with grains carrying long pinkish or white awns and shattering readily. It spreads from field to field, the grain being carried with the irrigation water. This is not a primitive form but only slightly remote from the cultivated type. When these wild plants are allowed to remain

in the field in the midst of the cultivated varieties, there is free natural crossing and the crosses give rise to progenies carrying various grades of the wild characters like awning and grain-shedding, and contaminate the whole field if left unchecked sufficiently early. Though rice is a self-fertilized crop, natural crossing appears to be very common and the percentage of such crossing is even greater in the wild types than in the cultivated forms. The cultivators do realize this and take special care to remove these wild plants as soon as they appear in the fields. In certain parts of the country as in parts of Bombay and Central Provinces, such wild types are a menace to rice cultivation and great pains are taken to keep them under control.

CHAPTER II

Climate, Water and Soil

Climate—Temperature and Latitude.—The mass production of this cereal is mostly confined to the South-Eastern portions of Asia, and represents some 57 millions out of the world's total output of 60 million tons per annum, excluding China. Heat is assumed to be the factor which determines the general limits of rice culture, both in latitude and altitude. Although rice is a tropical cereal thriving in regions of great heat and high atmospheric humidity, it is also successfully grown in the temperate zone. The crop is seldom successful where the mean temperature during the growing season is less than 75°F. In Japan, rice is cultivated as far as 42° latitude where the summer temperature is 70°F. and in Italy it reaches the latitude of 45°. An average of 95° to 105°F. is a suitable maximum for rice growing. While with sufficient water-supply it can stand even higher temperatures, it cannot tolerate too much of cold during the growing season. The greatest damage caused to the plant by cold is during the stage when it is forming tillers. In our own Province, the main difficulty with regard to the growing of the second crop in December-January in the Godavari delta, is the cold which inhibits the early growth and tiller production and makes the crop subject to insect pests.

The total temperature required to mature a rice crop (obtained by the addition of the mean daily temperatures throughout the growing period) has been determined in Spain and Italy for a number of varieties. This figure is said to vary between 2,500° and 4,000°. Similar figures calculated for our rices in Madras are very much higher than these. They vary from 7,500° for a three-month crop grown in Malabar during January to April, to 16,800° for a six-month crop in Tanjore grown in July to January. This temperature probably depends upon the duration of the variety and the locality and the season of the year in which it is grown. Great differences in duration often occur with regard to certain varieties according to the time of planting. The external factors which are responsible for the changes in duration are not known, but it is likely that the climatic factors do play an important part in such changes apart from the inherent character of the different varieties.

With regard to the heat and cold requirements of the crop, there is a great deal of variation among varieties. Varieties probably by long cultivation in particular regions get used to the climatic conditions prevailing there, and do not thrive under different conditions. We have often imported rices from Japan, Italy, etc., and attempted to grow them here, but because of the heat they ripen off too quickly to be of use economically. Similarly, varieties growing in the tropics if tried in, say, Italy, are not suitable. as the colder climate there delays flowering and ripening.

Altitude.—Rice can be grown even up to 7,000 feet above sea-level as in the Himalayas and is regularly grown at altitudes of two to three thousand feet as in Java and Madagascar. Even in our own Province, rice is successfully grown under such altitudes as in parts of Mysore, Wynad and Coorg. That low temperatures due to the high altitude also delay flowering has been observed in Gudalur on the Nilgiris (2,000 to 3,000 feet above sea-level), where, rice varieties of 4 to 5½ months in duration on the plains, take very nearly 6 months to ripen.

Light.—Apart from temperature it is likely the length of day has an important influence on the life activities of the plant. It resembles most of the plants in general in that the life period can be either lengthened or shortened by adjusting the light conditions artificially. Rice requires plenty of light generally though there are exceptions. The ash content of rice straw being high, large quantities of water must be transpired by the plant and hence the question of light becomes important. In Malabar there is a variety of rice, *chennellu*, which is grown successfully in shade under trees. Prolonged cloudy weather is generally considered detrimental to the crop particularly at the time of germination and when the crop is in flower.

We have no correct information about the requirements of rice with regard to atmospheric humidity but it appears to stand wide variations. The optimum conditions of rice growth under the varying conditions of temperature and humidity prevalent during the year, could be best found out by the analysis of the weather data throughout the year and classifying the same into definite groups or seasons. The analysis of the weather data for Coimbatore does not reveal the existence of such groups, as there is not any wide difference between the extremes both in temperature and humidity percentages in the different parts of the year. In Malabar, however, it is found that definite variations in humidity are obtainable in the different parts of the year, the maximum difference being from 66 per cent. to 93 per cent., though the temperature variations are not great.

Water.—The most important of all the requirements of the rice plant is an adequate supply of water. This may be available to the plant either as rainfall or as artificial irrigation. Rice is grown successfully in regions getting hardly 10 inches of rain during the year with the help of water pumped out from great depths as in California and it is also grown with the help of rains only as in Malabar, Philippines, etc., and in the latter case the season of the rice crop has to fit in with the rainy period of the tract. This important and broad difference, whether the crop is grown with irrigation or with the help of rain only, divides roughly the cultivation of rice into two categories, upland or dry cultivation and lowland or wet cultivation. The bulk of the rice crop of the world is grown under wet conditions where the plant grows in fields with standing water. Water in fact so dominates over

other climatic factors that with good irrigation facilities it is the safest of the world's great crops to grow. The choice of varieties, the preparation of the land and the cultural practices are all adapted to the quantity and the period of water availability. As a swamp crop requiring flooding at frequent intervals from the time it is sown until near its maturity, a five-months' crop requires about 70 acre inches of water. Even in Italy a five to six-months' crop is said to take about 100 acre inches. This is usually provided for by irrigation supplemented by the rains received during the growing period. In certain tracts as in Malabar where the topography does not allow an irrigation system, all the required quantity of water is supplied by the copious rains and the springs which are abundant.

Soil.—As regards soil requirements, rice is probably more cosmopolitan than any other crop. In the case of upland rice grown on hills as in Malabar *modan* lands, the crop does not appear to make a great demand on the soil which is here very open containing very little of organic matter. In the case of lowland rice as in the deltas, it is a plant adapted to heavy soils. While a typical upland or dry rice may be grown under lowland conditions, typical lowland rices do not thrive under dry conditions. Rice is a semi-aquatic plant and can thrive without much of oxygen. The heavy soils in which it is grown in addition to their being able to retain moisture for a long time when once irrigated, form an almost impervious substratum making the percolation of the irrigation water through them difficult as a result of preparing them by puddling. A most favourable condition is found when a loam overlies a heavy clay. The upper layer permits root development while the clay prevents drainage and holds the water that is so essential. Such soils are found along river valleys and on coastal lowlands particularly in the deltas of big rivers where the nearly-level surface is ideally adapted for irrigation. Typical rice soils contain a good proportion of the finer particles, clay and silt, about 40 to 60 per cent. Though good crops of rice are also grown in loamy and slightly open soils, these soils require replenishment of plant food much more than the heavy soils. Successive good crops of rice, about 3,000 lb. grain per acre are being obtained from some of the heavy soils as in West Godavari even without application of any manure. While the manurial requirements of rice will be dealt with in a later chapter, it may be pointed out that rice thrives best in soils rich in organic matter and hence the general response to the application of green manures. In fact throughout South India the practice of green manuring is very closely associated with rice culture.

Rice can tolerate a certain amount of acidity in the soils and in the heavy soils where oxygen supply is not abundant, the ploughing in of organic matter and its decomposition there result in making the soils slightly acid. Rice thrives also on decidedly alkaline soils where no other crop can grow. There are of course varietal adaptations with regard to the toleration of alkalinity in the soil.

CHAPTER III

Statistics

World position.—It is estimated that the world production of rice varies from 120,000 to 130,000 million pounds, a figure nearly equal to that of wheat. Seven hundred millions of people or more than half the earth's population live exclusively on rice. From about 119 millions of acres before the war, the area under rice had risen to 134 million acres in 1924–25 and continues to be at this figure with slight fluctuations. Asia forms the greatest centre of rice production. Nearly 95 per cent. of the world's rice area is concentrated in Asia and it contributes also about 95 per cent. of the world's production.

Although, as regards the quantity produced, rice approaches the principal agricultural products such as wheat and maize, the international trade in this cereal amounts only to a small fraction of the total production, whereas for wheat, the amount involved in the foreign trade is, on an average, about a fifth of the total production.

The three important rice producing and rice exporting countries of Asia are, India (including Burma), Indo-China and Siam.

Among the other Asiatic countries, China with its enormous production is a closed market. No statistics are available for China. Probably the area under rice in China is even greater than in India. Siam and Indo-China export, respectively, 1,200 and 1,000 million pounds. Nearly 2,000 million pounds of the rice requirements of the Pacific countries, have to be met by India (including Burma), Siam and Indo-China, and 40 per cent. of the production of these countries would meet this requirement. Although the production of Japan with her colonies is regularly increasing, she does import a certain quantity. When she has bumper crops she stops all imports except from her colonies. Her Government controls the prices in the country exempting rice imports from payment of duty when the crop is poor, and levying the duty in the event of a good crop. The Dutch East Indies import a certain quantity from India and from Siam. The Philippines draw their supplies mainly from Indo-China. China imports from Indo-China more than half its requirements. Since 1928 the zone of rice production has been pushed considerably north in North East Asia chiefly due to the Russian and Japanese enterprise. The Pacific countries are generally striving to increase their output of rice by increasing the area and by improving the acre yields. In the Philippines large areas are being newly brought under rice. In Europe and America rice production is much in excess of the demand thus releasing a considerable quantity for the markets, chiefly in Europe.

Position of India.—In India the chief rice producing provinces are Bengal, Bihar and Orissa, Burma and Madras. The area and production of rice in the several provinces are given below :—

TABLE No. 1.

Area and Production of Rice in British Provinces.

	Area (1,000 acres) average for		Increase or decrease per cent.	Production (1,000 tons) average for		Increase or decrease per cent.
	1922-26.	1927-30.		1922-26.	1927-30.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Assam	4,487	4,544	+ 1·3	1,527	1,464	— 4
Bengal	20,793	20,604	— 1·0	7,968	8,615	+ 8
Bihar and Orissa ..	14,446	14,015	— 3·0	4,636	5,466	+ 18
Bombay including Sind ..	3,068	3,142	+ 2·4	1,355	1,372	+ 1
Burma	11,996	12,691	+ 6·0	4,739	4,818	+ 2
Central Provinces and Berar.	5,193	5,486	+ 6·0	1,460	1,605	+ 10
Madras	10,968	11,285	+ 3·0	4,947	5,259	+ 6
United Provinces ..	7,178	6,902	— 4·0	2,168	1,709	— 12

When the export trade of the country is compared with the production, it is seen that Burma though contributing to only one-sixth of the total production, accounts for nearly 85 per cent. of the country's export. Taking the whole of India only 7 per cent. of her production comes for export whereas in Burma 38 per cent. of her production is exported. Bengal and Bihar and Orissa in spite of their big production do not figure much in export because most of the produce is actually consumed by the enormous population. Burma because of her very thin population is able to release a large portion of her produce for export. Due to a big increase both in area and output of rice in Siam and Indo-China within recent years, they are having increasing exportable surpluses and are coming into competition with Burma in all her markets particularly in the East—Japan, China and Malaya. If we compare the percentage area under rice with the total rice area of India, Bengal has 26·2 per cent., Bihar and Orissa 18·2 per cent., Burma 15·1 per cent. and Madras 13·9 per cent.

Position of Madras.—Among the Indian Provinces, Madras occupies the fourth place in rice area and the third place in rice production. In spite of her big production she has, mainly due to her large population, very little exportable surplus. In Madras the area under rice is 11·4 million acres which form about 29 per cent. of the total area under cultivation. Comparing the annual average acreage for the three quinquennia between 1918–1933, it is found that though the area under rice was lower during the second quinquennium, it went up again considerably in the third, so that the average area now is nearly 250,000 acres more than ten years ago. As regards average outturn per acre for the three periods, they were 1,736, 1,745 and 1,717 lb. rice in husk and the total outturn for the Province for the period 1928–33 has been 433 and 578 thousand tons more than in the periods 1918–23 and 1923–28, respectively.

Fluctuations in area and production.

TABLE No. 2.

Statement of Annual Average Acreage and Total Estimated Outturn of Rice for the three quinquennia 1918-33.

Acreage.

		ACS.	ACS.	ACS.
Period—				
1918-23	.. ..	11,155,735	11,155,735	..
1923-28	.. ..	10,896,173	..	10,896,173
	Decrease ..	259,562		
1928-33	.. ..	..	11,406,002	11,406,002
	Increase ..	..	250,267	509,829

Outturn in Rice in husk.

		TONS.	TONS.	TONS.
Period—				
1918-23	.. ..	7,483,978	7,483,978	..
1923-28	.. ..	7,339,144	..	7,339,144
	Decrease ..	144,834		
1928-33	.. ..	..	7,917,310	7,917,310
	Increase ..		433,302	578,166

There are wide fluctuations from year to year both in area and in production. Such fluctuations in area and outturn are common features of this Province because of the wide range of seasonal conditions under which this crop is grown in this Presidency. The rice area is divided into two broad groups (1) irrigated, that dependent on an irrigation system, rivers, canals, tanks, spring channels, etc., and (2) unirrigated, that dependent exclusively on rainfall. Out of the 11·4 million acres under rice, 8·13 millions (72 per cent.) are irrigated and 3·27 millions (28 per cent.) unirrigated. The rice crop of the West Coast districts (Malabar and South Kanara 1·3 million acres) depends exclusively on rainfall. Roughly 50 per cent of the rice area in Ganjam and Vizagapatam districts is unirrigated. Next in order comes the crop in the districts of Chingleput, Chittoor and Ramnad, where a major portion of the rice crop which is rainfed in its initial stages of growth is irrigated after the receipt of the north-east monsoon rains. Taking the whole of the irrigated area in the Province, 75 per cent of it is devoted to rice. Even the irrigated areas are not absolutely free from the vicissitudes of the season. The total area irrigated from the different sources of irrigation shows that 5½ million acres are irrigated from tanks and wells, whose regular and timely supplies are to a large extent dependent upon the two monsoons which are often inadequate in the Central districts, and sometimes untimely and excessive in the Coastal districts. The actual quantity of rice produced in any year in the Province is thus mainly dependent on the strength and distribution of the two monsoons.

Considering the area and production of rice in the several districts of the Province it is found that the areas and production are rather concentrated in the deltaic districts of Tanjore, West and East Godavari, Kistna, etc. The acre yields are different in different districts, they being particularly low in Ganjam and Malabar. Such variations are due to the natural facilities available and to the general soil differences with regard to fertility.

Madras produces besides rice, a fair amount of millets, which are consumed in the Province. The total quantity of cereal available, rice and millets, for consumption in the Province is 8,674 thousand tons. The quantity of net normal imports of rice (total imports less exports) comes to about 200 to 300 thousand tons. This, added to what is produced in the Province allows about $1\frac{1}{2}$ lb. of rice per head per day for the adult population (taking the adult population to represent 75 per cent of the total population) which is probably a satisfactory ration according to Colonel McCarrison's estimates. It will thus be seen that in a normal year the Province has to import but a very small quantity to meet her requirements. But in an abnormal season this import has to be increased.

Exports and imports—Exports.—The small foreign export trade of the Province in rice is concerned only with Ceylon and Malaya. Table No. 3 below gives the quantities of these exports during the last five years :—

TABLE No. 3.

Foreign Exports from Madras Presidency.

—	Year. 1929-30.	1930-31.	1931-32.	1932-33.	1933-34.
	TONS.	TONS.	TONS.	TONS.	TONS.
Ceylon—					
Rice	88,447	96,218	56,505	59,941	72,007
Paddy converted into rice.	2,732	2,563	1,448	1,340	721
Malaya States and Straits.	5,308	5,461	4,625	4,447	3,264
Total exports from Madras ports in term of rice ..	96,487	104,242	62,578	65,728	75,992

The chief districts of Madras which are concerned in the trade are Tanjore, Godavari and Kistna. There has been a general decline in this trade in recent years.

The exports of rice from Madras within India are mainly to Mysore, Hyderabad, Bombay-Deccan, and to a small extent to Travancore, Cochin, Pondicherry, etc. The main limiting factor to the further expansion of these exports is the rather high railway freight which with the present low price for the produce makes an unduly large proportion of the production costs. The serious

difficulty with regard to the expansion of this export is due to the competition of the foreign cheap rices that arrive in the ports and get distributed into the interior.

The imports into the Presidency may be conveniently classified into (1) foreign imports, (2) coastwise imports and (3) imports by rail and road from other provinces and adjoining States.

Under (1) comes the imports from Siam and Indo-China, under (2) those received from Burma and under (3) the imports from other provinces. The total quantity of such imports which was only 200 to 300 thousand tons on the average, until 1930, has risen to about 300 to 500 thousand tons during 1933–34 chiefly due to the large imports from Siam.

CHAPTER IV

Rice Cultivation

(i) *Variation in methods.*—Just as the varieties of rice and the soils in which they are cultivated vary, so also the method of cultivation varies from place to place in this Province. Probably in no other province of India and also in no other crop do such variations exist. As was pointed out previously the two big divisions in the method of cultivation are, the dry cultivation and the wet or swamp cultivation. The former both in extent and in output is of very little importance while the area under the latter system is very extensive and contributes most to the total production in the Province.

Dry rice.—In parts of West Coast, Malabar and South Kanara, and in the Agency tracts of Ganjam and Vizagapatam districts rice is raised as a purely dry crop. Even in this dry cultivation, there are two systems, one being more primitive than the other. In the more primitive one which is known as *kumeri* cultivation in South Kanara and *punam* cultivation in North Malabar, the slopes of the hills are first cleared of the jungle by cutting and burning and the rice is grown on the cleared ground. After one or two crops are taken, the land is left to develop the jungle again. Since most of the land available has already been brought under cultivation there are practically no possibilities of extending this destructive method of cultivation. The '*podu*' cultivation of the Vizagapatam Agency tracts practised by the hill tribes corresponds to the *kumeri* and *punam* cultivation of the West Coast. After the clearing of the jungle, dry paddies are sown mixed with redgram, cotton and *gogu*. Sometimes this is followed by a gingelly crop.

A slightly advanced method of the above is practised in South Malabar and is known as *modan* cultivation. Here the land is terraced and no jungle springs up again. Even in this method the land is now and then left fallow for a year or two to recuperate between two or three crops of rice. Cotton may also be grown mixed with rice.

In Kistna and Godavari uplands there obtains a different method of dry cultivation. While the soils used for the dry cultivation in Malabar and South Kanara, are poor open laterite soils often mixed with gravel, those of the Kistna and Godavari are deep heavy black soils. Here the rice known as the *budama* is grown between lines of redgram. By the time the redgram shades the space between, the rice gets matured.

Semi-dry rice.—From the purely dry method there is a practice prevalent in parts of Chingleput, Nellore and Kurnool districts where the rice is first sown as a dry crop in the early stages. But

in the later stages of the crop, about two or three months after sowing, when water-supply is usually available with the break of the north-east monsoon, the crop is treated as a wet crop. The same practice obtains in Kollegal taluk of the Coimbatore district, but here the rice is sown mixed with a number of other crops and vegetables which give some produce before the tanks get filled with the monsoon rains. In parts of Ganjam and Vizagapatam districts the above method of sowing the crop dry is followed, but the land is ploughed and the rice is sown dry taking advantage of the early showers and water is turned on as soon as the south-west monsoon breaks out and water becomes available for irrigation. Here the period through which the crop remains dry is shorter than in the previous case. In both cases the sources of water-supply are usually rainfed tanks which get filled with the monsoons.

Garden land rice.—There is thirdly the practice of growing rice as a garden crop with the help of lift irrigation from wells. This practice is seen in several of the southern districts but is most extensive in North Arcot, Salem, South Arcot and Chingleput districts. In addition to the use of mhotes worked by bullocks, wherever the water table is high the water is often baled out by *picottahs* with human labour. In parts of Chingleput district the use of oil engines to pump water for the rice fields is not an uncommon feature.

Wet rice.—Finally there is the most important and most extensive wet cultivation practised all over the Presidency wherever water-supply is assured. The most advanced stages of this typical wet cultivation is to be seen in the deltaic regions and in the river valleys. Here the irrigation is all from river canals and spring channels which have an assured supply of water for definite periods. The areas commanded by the big irrigation systems of Godavari, Kistna, Cauvery, Pennar, Periyar, Tambaraparni, etc., all come under this category. There are also minor irrigation systems of small rivers and big irrigation tanks in several parts of the Presidency where also such wet rice cultivation is practised but the water-supply is not usually so dependable as in the above.

Size of fields and bunds.—The size of the rice fields under wet cultivation varies considerably from tract to tract. It is purely a question of the level of the land in the tract. It may vary from a few cents to a few acres. In the terraced lands on the slopes of hills as in Malabar and South Kanara, the size will depend upon the contours. In the deltas where the level does not fall more than a foot per mile, the fields are very much larger. Generally the average size will be about 10 to 20 cents. While smaller fields result in waste of cultivable area by the numerous bunds, levelling of the fields which is necessary can be more thorough there. In very large fields it is often difficult to level properly and in Tanjore in some of the larger fields of an acre or two in area, it is not

unusual to see the land drying up at one end while there may be five to six inches of water at another end. The size of the fields under well irrigation is necessarily small to control the irrigation.

The size of the field bunds also varies, more or less depending on the size of the fields. Apart from the size, it must be sound enough to impound water efficiently. In vast stretches of rice lands, the field bunds are the only means of moving about and it will not be convenient to have them too small. In Godavari and Kistna deltas while the big bunds which are not used as pathways are utilized to grow some pulse or vegetable crops, no such use is made of the bunds in Tanjore.

Due to the deposition of silt brought with the irrigation water in the fields, the level of the fields often changes in Tanjore. Apart from the fine levelling which may be done at the time of puddling, some gross levelling is also done during summer when shallow and long trenches are dug along the high level portions of the fields and the clods removed are spread on the lower portions. After water is let in for ploughing the sides of these trenches are dug and levelled. Sometimes this dug out earth is heaped in a corner of the field and by accumulation after some years it becomes a small dry land bit that could be used as a threshing-floor.

(ii) *Season and varieties.*—Whatever may be the method of cultivation adopted, the rice season throughout the Province, except probably to a small extent under well irrigated areas, synchronizes with the two monsoons. The three distinct seasons of Madras are—

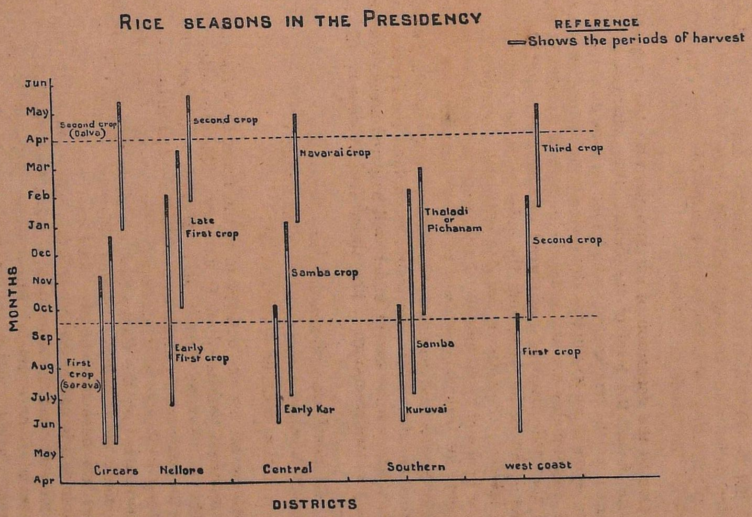
(1) South-west monsoon—June–September.

(2) North-east monsoon—October–January.

(3) Hot weather—February–May.

Almost all the rice cultivation of the Province is confined to the two monsoon periods—June to January. The crop either gets the benefit of the rains directly as in Malabar and South Kanara or gets its water-supply from rivers which depend upon the monsoon for their freshes as in Trichinopoly, Tanjore and Godavari. There are rice areas on the East Coast which do not get the benefit of the south-west monsoon either directly or indirectly and are exclusively dependent on the north-east monsoon. Usually these areas have a large number of irrigation tanks which get filled during this monsoon and the rice season extends from October to January. In special isolated tracts where water facilities extend beyond February, a hot weather crop of rice may also be grown between February to May as in the Godavari delta.

It must be stated in this connexion that each rice tract has its own special set of varieties suited to the conditions obtaining there and though there are instances when a variety introduced from one tract into another has proved a success, indiscriminate introductions have often led to failures. One important change in a variety that


RICE SEASONS IN THE PRESIDENCY
REFERENCE
Shows the periods of harvest
MONTHS
Jun
May
Apr
Mar
Feb
Jan
Dec
Nov
Oct
Sep
Aug
July
Jun
May
Apr
Second crop (Dalva)
First crop (Sarava)
second crop
Late First crop
Early First crop
Navarai crop
Samba crop
Early Kar
Thaladi or Pichanam
Samba
Kuruvai
Third crop
Second crop
First crop
Circars
Nellore
Central
Southern
west coast
DISTRICTS

is often brought about by moving it to a new place is the alteration in the duration of the crop. There are several examples on record in the experience of the Department of large variations in the crop due to the seasonal and climatic changes resulting from change of place.

Number of crops grown.—Though the majority of the rice area of the Province consists of single-crop lands, where a variety of five to six months' duration is grown, it is usual in portions of the area with better water facilities to grow two crops of rice in the same season one followed by the other. This practice obtains in parts of Tinnevelly, Madura (Periyar valley), Trichinopoly, Tanjore and Godavari districts. These areas are such that they get the benefit of both the monsoons, the total annual rainfall varying from 40 to 50 inches. The first crop is mainly dependent on the river irrigation and the second partly on irrigation and partly on north-east monsoon rains. In Malabar and South Kanara, however, both the crops wherever they are grown, depend exclusively on the rains and springs activated by the monsoons. In small areas there is even a third crop raised by lift irrigation from springs and wells, but this cultivation is rather precarious. There are facilities for growing three crops of rice in the same land in certain limited areas commanded by the Cauvery irrigation system in parts of Trichinopoly district. In Godavari district, however, though the water-supply in the canals is available for nearly eleven months, June to April, the first rice crop is raised from June to November, and the cultivation of the second crop does not begin immediately, but is postponed to the middle of January to the middle of April, no use being made of the canal water between November to January. The special disabilities which are the causes of this practice will be dealt with later.

Age of the crops.—Where two crops are raised, one is usually of a short duration and the other of a long duration. Which of these is to come first depends upon the water facilities and the occurrence of the monsoons with reference to the individual tract. In all the double-crop areas except that of Godavari, the short duration rice is always followed by the long duration one. In Godavari, however, the long duration rice is grown first and the short duration one comes later. In the Tamil districts the short first crop is called *kar* which includes a large number of varieties of three to four months in duration and the long second crop is called the *samba* or *pishanam* which again includes a large number of varieties of five to six and a half months in duration. In the double-crop areas of the Cauvery delta, in Tanjore district, in the upper portions of the delta where water is received early in the season, a *kar* of a longer duration (four months) is grown while in the lower reaches, the *kuruvai* of a shorter duration (three months) takes its place. In the Telugu districts, the first long crop is called the *sarava* and the second short crop is called the *dalwa*, each of them comprising again a large number of varieties. The main principle involved in

the choice of varieties for particular tracts is that the heavy rainy period should not synchronize either with the sowing or harvesting seasons. In North Malabar and South Kanara there is no sharp distinction in age between the first and second crop varieties, both of them being nearly of the same duration. In South Malabar, however, we find both the short and long duration varieties in both the seasons. From the above it will be seen that the bulk of the rice harvests comes between the period, December to February, while some small quantities may be expected in September to October and later in April to May.

While in tracts with an assured and unfailing supply of water, the number of varieties grown is comparatively few, all nearly of the same duration, in tracts which depend upon either the monsoons or on irrigation tanks which get their supply from the monsoon rains, the varieties are rather more, differing in their durations. This is due to the time at which the tanks receive their water, i.e., the season, and the quantity of water which may be expected in the tank. Portions of Ganjam and Vizagapatam districts represent such tracts.

There are again special localities here and there which have their special varieties, and special methods of cultivation. In certain parts of the Tanjore district for instance, there is an eight-month's variety, *ottadan*, which is grown mixed with a short duration three-month's crop. Similarly in parts of the West Coast in what is known as *karinkora* lands which are low-lying and allow water to stagnate to a depth of several feet, a long duration variety of over seven months is grown in summer when the water level goes down and the land gets nearly dry.

Then there are certain special conditions in various parts of the Province which require special cultivation practices, such as, portions on the West Coast subject to the inundations from the sea, areas adjoining back-waters, areas where the soil is alkaline, etc., which will be dealt with later separately. By long experience people are in possession of special varieties suited to such special conditions.

(iii) *Preparation of the land for rice.*—This may be considered under three heads :—

(1) a pure dry crop,

(2) a semi-dry crop, and

(3) a pure wet crop.

Dry and semi-dry crop.—This naturally entails the preparation of the land in time so that the seed can be sown immediately on receipt of showers with the break of the south-west monsoon. The conditions where this practice obtains vary widely in different parts of the Province. Generally it is a precarious cropping as the success entirely depends upon a favourable monsoon. The lands are ploughed in summer a number of times to get the necessary tilth

and any available manure is also spread. The sowing of rice is usually done in May–June. The tracts usually get an average rainfall of 20–30 inches during the growing season (except in parts of Malabar and South Kanara where the rains are very much heavier) and fair crops may be expected. Except in uplands of the Godavari delta, the soils where this cropping obtains are usually of a light loamy nature and not inherently fertile.

Under (2) semi-dry crop, there are two classes, one in which the seed is sown in anticipation of the south-west monsoon and the other where the sowing is done in anticipation of the north-east monsoon. The preparation of the land for both does not differ from that for No. (1).

The preparation of the land for (3) might be either for directly broadcasting in puddle, or for transplanting, and the process is practically the same for both.

Preparation of the land in the heavy delta soils.—On the heavy soils characteristic of the deltas where the crop is invariably transplanted, the preparation of the land in hot weather is impossible. The soil after the harvest of the previous crop dries very hard and fissures 18 to 24 inches deep are formed. For such soils, ploughing dry in summer, even if possible, is considered harmful. The land is not usually touched but left fallow until irrigation water is available. Then the fields are flooded and after the soil is well soaked, the ploughing starts. If there is any green manure crop on the fields as is common in parts of Kistna and Godavari, the plants are pulled out and trampled into the mud. Even when there is no green manure crop, if green leaves can be obtained from the adjacent forests as in parts of Madura, Salem and Coimbatore, they are brought in head loads, spread over the fields and are trampled in. The fields are kept flooded to help in the rotting of the green leaves. After the lapse of some time, the fields are again ploughed repeatedly three to four times until the mud is stirred up into a soft puddle. The fields are then levelled with a levelling board and they receive the seed, usually sprouted, either directly or they are transplanted with seedlings raised elsewhere. The final and the most important operations before either direct sowing or transplanting are trimming of the bunds, removal of weeds and grass growth on them and making them water-tight by closing all depressions and holes with soft mud.

Harmful effects of dry ploughing heavy soils.—That the heavy soils are damaged by dry ploughing in the hot weather resulting in a poor outturn of the following rice crop has been well established by a series of experiments conducted at the Agricultural Research Stations, Samalkota, Maruter and Aduturai.

Samalkota.—At Samalkota where the soil is a heavy black alluvium, an experiment was conducted for four seasons from 1911–1915 in which a portion of the field was dug up immediately after the harvest of the first crop in November and left in rough

clods while the other portion was left undisturbed. When rice was transplanted later after puddling, it was found that in all the four years, the crop on the dug plots appeared thinner and did not cover the ground so well as in the uncultivated plots and the yields of the latter were always higher than on the dug plots, by 10 to 30 per cent.

In another experiment carried on again for four seasons from 1909 to 1913, one portion of the field was left undisturbed after the harvest of the rice crop and the other portion was cultivated a number of times. The uncultivated portion was puddled and then transplanted whereas the cultivated portion was planted without puddling. Even though the cultivation of the non-puddled portion was not quite so thorough as in the previous experiment the results obtained were very nearly the same. Though the yield figures in favour of the uncultivated and puddled plots were very variable from year to year, the increase was very marked amounting in some years to nearly 50 per cent. of the yields in the non-puddled plots.

A similar experiment but in a modified form was started again in 1928–29 and had gone on until 1932–33. Four pairs of 10 cent plots were laid out. One of each pair of plots was puddled and planted in the usual way and the other dry ploughed, irrigated and planted. In the case of one of the dry ploughed plots, the operation was commenced soon after the harvest of the previous rice crop in November while in the case of the remainder the ploughing was done after the break of the south-west monsoon in next June. The yields of dry ploughed plots were always lower than the puddled plots as before and the fall was much more prominent in every year in the case of the plot dry ploughed immediately after the harvest of the rice crop. The fall in the yield of the winter dry ploughed plot varied between 15 to 35 per cent. during the six years of trial, while in the case of summer dry ploughed plots the fall was never more than 25 per cent., and in some years the drop in yield was almost insignificant. The experiment had been modified later by including another plot to the series which was dry plouged in summer after the break of the south-west monsoon but was puddled again just before transplantation. There was an indication here that the harmful effect of dry cultivation could be counteracted to a certain extent by the action of puddling the fields at transplant time.

Aduturai.—An analogous experiment was conducted for four seasons from 1930 at the Agricultural Research Station, Aduturai. Here also the soil is a heavy clay loam and it is usually left fallow between February to June. In the double crop area, one of the fields was laid out into plots and alternate plots were ploughed in May taking advantage of the rains received then. When seedlings were ready for planting all the plots were puddled and transplanted. The crop in each of the plots was harvested separately

and the yield recorded. It was found that the average yield of the dry ploughed plots was definitely 10 per cent. less than the average yield of the non-ploughed. The harmful effect of the dry ploughing had, however, disappeared in the *samba* crop following. The experiment was modified later to see whether the harmful effect of summer ploughing might be modified by fertilizing the plot. Half the area of the dry ploughed and non-dry ploughed plots was given a manurial application of green leaves at 4,000 lb. plus one hundredweight of super phosphate per acre. It was found that the harmful effect of dry ploughing had been counteracted by the manurial treatment. The yields of unmanured fallow plots were the same as the dry ploughed and manured plots while the manured fallow plot yielded distinctly better by about 10 per cent. This experiment was also repeated in single crop lands and the results were practically the same pointing out clearly that the disturbance of the soil in the hot weather was bad for the succeeding rice crop. The results of analysis of the cultivated and fallow soils of these fields failed to show any difference in chemical composition or nitrifying power.

Allowing the soil to dry up completely in summer and the puddling adopted later probably brings about such a condition in the physical texture of the soil as is beneficial to the rice crop. The digging or ploughing in summer prevents the soil in the bottom layers to dry up completely.

In some cases the heavy rice soils have got to be disturbed in the hot weather if a green manure crop is to be raised in the fields. So long as this green manure crop is ploughed in, the disturbance of the soil in connexion with the sowing of the green manure crop brings on no harmful effect. This has been the experience at Maruter and Coimbatore.

That the dry ploughing of the rice soils is harmful only in the case of heavy clay is apparent from the results of an experiment conducted at the Agricultural Research Station, Palur. Here the soil is a sandy loam and the ploughing of the soil in summer has no harmful effect on the succeeding rice crop.

That even the harmful effect of dry ploughing is noticeable only in rice grown as a wet crop but not in a pure dry crop, is borne out from another experiment conducted at the Agricultural Research Station, Samalkota. As has been mentioned already, in portions of the Godavari delta there is a pure dry crop of rice grown in the black heavy soils. To compare the results of digging up the soils in summer in such dry cultivation, some of the plots in the dry area were dug up and left to weather side by side with some fallow plots. When the dry rice was grown on all these plots and their yields compared it was found that the yield of rice in the dug plot was almost 25–35 per cent. more than in the fallow plot, just the converse of the results obtained with the wet plots.

With the deep heavy soils of Godavari, specially in the Western delta, it has been the experience that if the summer is rainless resulting in deep and wide cracking of the soils, the succeeding rice crop comes up most luxuriantly even without any application of manure. The beneficial action of the application of green manure is not apparent in such seasons. Often even the elaborate ploughing and puddling is dispensed with in such seasons. It is the common experience even in Tanjore delta that with a dry, hot and rainless summer the yields of the first *kuruvai* crop are very satisfactory.

In the case of the well irrigated rices the preparation of the fields entails great care and thoroughness. In the districts where rice is grown in this way like North Arcot, Salem, Madura, etc., the soils are generally of a light and porous nature and unless the field is well prepared, the water will drain off too soon. The soil is ploughed frequently, sometimes even a dozen times to break the particles into as fine a condition as possible so that the irrigation water will not drain down too rapidly. During the later ploughings done in puddle sheep are let into the fields to trample the mud as the ploughing is being done, so that the soil below will get consolidated and become almost impervious to water.

In some parts of the Godavari delta where the land is low-lying, ploughing begins shortly after the removal of the first crop and is kept up until the transplanting season comes round again. Here no second crop is taken and the operation of puddling is omitted. This practice is adopted because the land when irrigated becomes very soft and it is difficult to plough owing to the depth to which the cattle sink into the ground. There are also certain portions in West Godavari where the fields are continuously kept under puddle, *thandu thatupu*, and here also ploughing is not feasible.

(iv) *Sowing and transplanting—Sowing.*—Of the two practices, direct sowing and transplanting, the latter is by far the more important and it may be said that wherever facilities for transplanting obtain, people will prefer it to broadcasting. Broadcasting is often practised in the case of (1) short duration crops, (2) where the land is poor and the yield is likely to be small, (3) where labour is insufficient at the proper season to transplant or (4) where water is insufficient to allow transplanting in the proper season. Thus in South Arcot the first short crop of three to four months in duration, is almost invariably sown direct. In malarial tracts where the crop is dependent largely on the rainfall as in the interior of Ganjam, Vizagapatam and the West Coast, broadcasting is commonly practised since labour is particularly scarce when the rains commence. In South Malabar the bulk of the first crop, i.e., the main crop is broadcast, as the crop has to be in when the southwest monsoon bursts. The land is already prepared dry and if

transplanting is to be adopted there would not be sufficient labour to get the whole crop on in the proper season. Weeding expenses are very heavy in a broadcast crop but there is not probably the same urgency about this work that there is in getting the crop in the season. In parts of Kurnool, Nellore, Chingleput and South Arcot districts, the crop has to be started before water is available for irrigation and therefore transplanting is impossible. The comparative merits of direct sowing and transplanting have often formed the basis of experiments conducted at several of the departmental research stations and these will be discussed later. It is still possible to introduce transplanting with advantage in certain cases and the departmental propaganda has been directed towards it.

Sowing dry rices and semi-dry rices.—The sowing may be done in any one of the following ways. (1) Broadcasting the seed and then lightly ploughing the land to cover the seed, (2) sowing the seed behind the plough furrows and (3) drilling the seed in lines. Usually a seed rate of 100 to 150 lb. of seed per acre is used for any one of these methods though the seed rate may be slightly less in the case of the drilled crop. It looks possible that there might be economy effected in the quantity of seed sown but as the success of the whole crop depends upon the timely break and a satisfactory continuance of the monsoons, probably there is too much risk involved in economising seed rate. If the crop is found to be too thick in broadcast fields, the plough is worked again after the crop has well germinated when the plants are about a foot high. This ploughing not only helps in thinning the crop but also removes weeds which in some places prove serious. This ploughing to thin out the crop has to be done judiciously at the right time. Sometimes great harm is done to the crop if the soil is disturbed when it is not in the right condition.

Broadcasting wet rices.—Here either the seed may be directly sown in a puddled and levelled field or sown in the seed-bed to be transplanted later. The broadcasting in puddle is usually practised only in the early varieties in double crop areas, and the seed is invariably sprouted before sowing. The seed to be sown is first put into a bag and immersed in water for a period of 12 to 24 hours when the bag is removed and the water is allowed to drain off. When all the excess water is gone, the bag is usually kept in a dark place and sometimes even covered over with straw and weighted. After the lapse of 24 hours, great heat is produced inside the bag and the grains just begin to germinate. By adjusting the moisture and warmth the germination may be either hastened or retarded according to the requirements of circumstances. Best results are obtained when the plumule is just showing through the glumes and no radicle has come out. If the germination is too far gone the sprouts stand the risk of breaking at the time of sowing the seed due to handling.

The seed is sown in the field with an inch of water over the soft mud. The water kept in the field at the time of sowing prevents the seed sinking into the soft mud. After the sowing is complete the water is drained off. Water is again let in after a day when the grain has sent its radicle into the soil and anchored itself. The watering has to be attended to carefully in the early stages by alternate irrigation and draining. There should not be too much of water given and at the same time the soil should not be allowed to go dry and crack on the surface. When the germination is all complete and the plants have grown a few inches, water is allowed to stand continuously. Sometimes, even in the puddled field dry seed may be sown, but the water remaining in the field at the time of sowing will have to be kept on for a day or two until the seed has well soaked and started germinating.

A seed rate of 100 to 150 lb. per acre, is not unusual for such direct sowings. There is possibly a great scope for the reduction in seed rate even for this sowing but it all depends upon how thorough the preparatory cultivation of the land has been. Reduction is possible only where the field is well levelled and where the irrigation can be controlled. It is not always possible to get a uniform stand of the crop however careful the sowing may be done. As in the dry rice, the fields are ploughed again when the crop is about a month or six weeks old which helps to thin out the plants and to remove weeds. The thinnings are used to fill up gaps and after this operation, there is nothing more to worry except watering.

Preparation of seed-beds for wet rice.—Sowing in nurseries and transplanting the seedlings at a later stage obtain in all the deltas and river valleys with an assured supply of irrigation water. There are three methods of raising the seed-beds—the dry, moist, and wet according to the method of preparing and watering. All the three are adopted in different rice tracts. The dry seed-bed is possible in such districts where a sufficiency of rainfall is assured and where the soil is sufficiently friable to retain moisture. Such seed-beds are seen in the West Coast. The moist seed-bed in many districts, Tanjore, Godavari, Tinnevelly, etc., takes the place of this dry seed-bed. Here the seedlings are kept growing by sufficient irrigation to keep the soil moist but not wet. There is not however much difference between the dry and moist seed-beds as the latter can be converted into the former when necessity arises. They are invariably adopted in all the important rice tracts for the first or early crops, the second or late crop being raised in a wet seed-bed. Periyar tract of Madura is, however, an exception, where for both the crops wet seed-beds are raised. The dry seed-bed has the advantage over the wet in places where the time of receipt of water for the transplanting of the fields is uncertain and where immediate advantage of the receipt of water is sought to be taken to transplant early. The growth of the seedlings is naturally

more rapid in the wet seed-bed and there is a possibility of the seedlings getting overaged if sufficient water for transplanting is not available in time. By cutting off the irrigation water in the dry or moist seed-bed, the growth is retarded and the seedlings can be left to remain in the seed-bed as long as it is necessary. In the case of the wet seed-bed it cannot be allowed to dry up without serious damage to the seedlings. The seedlings of the dry seed-bed are generally considered hardier and more capable of withstanding adverse conditions than those of the wet seed-bed.

The preparation of the seed-bed is done with great care, the most fertile portions of one's holding being used for the seed-bed area. All the available manure, which is not too abundant in the case of the ordinary ryot, is applied to the seed-bed. The manures ordinarily used are ashes or cattle-manure. The dry or moist seed-beds have to be prepared in summer by repeated dry ploughings taking advantage of the rains that may be received until a fine tilth is obtained. The seed-beds of the delta lands in Tanjore and Godavari are usually those nearest the village with some water facilities either in the shape of a well or a tank in the neighbourhood. Beds are then formed, the seed either sprouted or dry, more often the latter, is then sown and irrigated. The beds are kept moist until the grains have germinated and thereafter the irrigations are so adjusted as to give the required quantity of water.

The preparation of the wet seed-beds does not in any way differ from the preparation of the transplant field. These usually get a dressing of green leaves up to 6,000 to 8,000 lb. per acre early enough to get well decomposed before the sowing. Invariably sprouted seed is used for the wet seed-bed. After the germination is complete, the bed is kept flooded until the seedlings are ready for transplanting.

Connected with the raising of seed-beds there are many problems requiring investigations. They are—

(1) Comparative merits of the different methods of raising seed-bed, wet and dry;

(2) the optimum seed rate to be adopted; comparison of seedlings from thick and thin sown nurseries;

(3) the optimum number of seedlings to be planted per hole in the field;

(4) the optimum spacing between plants in the transplant field;

(5) the optimum age of the seedlings to be planted;

(6) the influence of season, variety and the fertility of the land on transplanting practices; and

(7) comparison between direct sowing (broadcasting) and transplanting.

While the first two of the above refer to the seed-bed, the others refer to the transplanting of the seedlings. All these are inter-related and to get satisfactory results, they must all be tackled together. These problems have formed the subject of study and experimentation of probably every rice-gowing country. The results of an experiment conducted at any one centre can only be of limited value to other places especially when the varieties grown, climatic conditions, and agronomic practices vary widely from place to place. This obviously necessitates the carrying out of suitable experiments at every suitable centre. These problems have been investigated at Samalkota, Maruter, Palur, Aduturai, Coimbatore, Pattambi, etc. Though some of the earlier experiments have not been laid on proper lines according to the modern ideas of experimental technique, yet, the results have proved valuable enough in throwing indications and advancing our knowledge about these problems.

Wet and dry seed-bed.—The comparative merit of seedlings from a wet and a dry nursery has been under investigation at a number of centres. It formed a subject of an experiment for four years at the Paddy Breeding Station, Coimbatore, from 1925–26 to 1928–29.

The method of preparing a dry nursery adopted at Coimbatore is described below and it must be applicable to all parts of the Province except that the methods of manuring, and final sowing may vary in different tracts. Taking advantage of the usual summer showers in March–April, the land chosen for the nursery is broken with a plough. If rains fail or are not sufficient, the land may have to be first irrigated and then ploughed at the right condition. The ploughings are repeated at intervals to get the tilth and sometimes the clods may have to be broken if too dry. The usual manure applied is either sheep-penning at 5,000 sheep per acre or village cattle manure at 20 cart-loads (about 12 tons) per acre. After the manure is spread the ploughing is again repeated taking advantage of any rain that might be received until a fine tilth is obtained. The sowing of seed is done usually about six weeks earlier to the time of transplanting. At the time of sowing, the land is once again ploughed, levelled and beds of convenient sizes formed. After the seed has been covered the beds get a soaking irrigation. A sprout irrigation is again given on the third day. These two irrigations may, usually be sufficient, and when the seedlings are ready for transplanting the beds are again irrigated and the seedlings are pulled. If, however, the season is too dry and the seedlings are not making satisfactory progress a further irrigation before the final one might be necessary.

The preparation of the wet nursery begins after the break of the monsoon when irrigation water is available. The field is just flooded, ploughed once or twice in water and the bunds are trimmed and made water-tight. Green leaves which take the

place of sheep-penning or cattle manure in the dry bed is spread over the area and trampled in. The field is kept flooded and when the green leaves have decomposed, say in about three to four weeks, the field is ploughed a number of times until the soil is stirred into a soft puddle. It is then levelled and beds of convenient sizes are formed. Sprouted seed is sown in the bed. The irrigation and draining is done carefully for a few days until the seedlings have all come up and after about two weeks, water is allowed to stand permanently in the field until the seedlings are ready for planting.

There is not much difference in the cost of raising seedlings by the two methods. It costs about Rs. 10 to Rs. 12 to raise a nursery enough to plant one acre including ploughing, cost of manure, cost of seed, etc.

During three years the wet and dry seed-beds were prepared on the farm under identical conditions for two varieties Co. 3 and GEB. 24 and their yields compared. The differences between the dry and wet seedlings were not definite in two out of three years, and the probability is that there is not much difference between the productive powers of the two kinds of seedlings.

An experiment of a similar nature was conducted one year at the Agricultural Research Station, Aduturai, with three *kar* (first crop) varieties. The usual practice obtaining in the delta is only dry or moist nurseries for the first short crop and wet nurseries for the late second crop. A trial was made to grow wet nurseries for the first crop and the seedlings obtained were compared against the seedlings obtained from the usual dry or moist nurseries. Of the three varieties compared Adt. 3, Adt. 4, and *sarapalli*, the yield difference in favour of the dry nurseries was over 20 per cent. in the case of Adt. 3 and Adt. 4 and in the case of *sarapalli* the difference was as much as 32 per cent.

Experiments have also been conducted at the Agricultural Research Station, Pattambi, to compare the merits of dry and wet nurseries for a first crop variety, *aryan*, but the results did not show any difference between the two. A large amount of experimental work has been done at the Agricultural Research Station, Maruter, in connexion with the advancing of the second-crop season. It was shown that different methods of raising dry nurseries could be made use of as one of the means of advancing the harvests.

Seed rate.—This is a variable quantity and it forms more or less an indication of the standard of cultivation attained, the rate being usually higher in the backward tracts. The minimum can be anywhere near 8 madras measures (20 lb.) of grain and the maximum up to 50 to 60 measures. This quantity sown in five to seven cents of land is expected to give enough seedlings to transplant an acre. The ratio of the seed-bed area to the transplant field may vary between 1 : 8 and 1 : 20. In parts of Malabar

the ratio may be even as narrow as 1 : 4 or 1 : 5 as the seed-beds here are usually raised with the precarious hot weather showers and the germination of the seed is consequently uncertain. In Kistna, however, where the ryots are always more enterprising and where economic transplanting has been in vogue even before the Department started its propaganda, the ratio is much wider.

A field planted with seedlings singly four inches apart, i.e., with 16 square inches to each plant, should need theoretically about 400,000 seedlings per acre, a number which except in the coarsest varieties, could, probably, be obtained from not more than 20 lb. of grain. Considerable research has been carried on the seed rate and the amount of seedlings required to transplant an acre. It may now be said with confidence that for an ordinary wet seed-bed well prepared, about 18 to 20 lb. of seed sown in about seven to eight cents of land (roughly one madras measure per cent) should be quite enough to transplant an acre. Though this rate may be an optimum for any ordinary variety of Madras such as *nelloresamba* or *krishnakatukkullu*, it may require modifications either when the grain is very small or very coarse. A variety like *jeeragasamba* has got very fine grain and obviously a pound of seed will contain a much larger number of grains than others and hence it might be possible to plant an acre even with about 8 to 12 lb. of seed. On the other hand, in the case of varieties like *basangi* and *kar*, because of the bigger size of the grain the quantity may have to be increased. It will always prove a useful practice to adjust the seed rate according to the size of the grain.

The propaganda of the Department advocating single-seedling planting in earlier years was intimately connected with the seed rate to be adopted. Single planting or economic planting is only possible when the rate of sowing of seed-bed is low. The emphasis of the propaganda about economic planting is mostly in the saving of seed used in the seed-bed. This saving could easily be of the value of Rs. 2 to Rs. 3 per acre. It has been calculated that the saving in seed that has been effected in one important rice district, say Tanjore, would be enough to feed the whole population of the district for three weeks every year. Thin sowing of seed-bed has been taken up practically in every rice tract particularly in districts south of Madras. In Tanjore, until 15 years ago, the ryots were using about 60 to 100 lb. of grain to transplant an acre and it might be said that the present average cannot be more than 30 to 40 lb.

Thick and thin sowing of seed-beds.—Irrespective of how the seed-bed is sown, the seed rate adopted affects the condition of the seedlings, thinner sowings giving rise to strong and sturdy seedlings and thicker sowings to poor and weak seedlings. Whether there is any difference in the productive power between the thick-sown and thin-sown seedlings has been investigated at a number

of stations, Coimbatore, Maruter and Samalkota. The first preliminary experiment done at the Paddy Breeding Station, Coimbatore, in this connexion may be of some interest.

Even in an ordinary sown seed-bed it can usually be seen that the seedlings on the borders of the beds, due to the extra space, are better developed, sometimes even with additional tillers. Such strong tillered seedlings can be seen even in the middle where gaps have occurred due to some of the seedlings dying off earlier. The seedlings in the centre of the beds and where the seeds have fallen thick should be on the other hand non-tillered and rather weak. To see whether such differences in the condition of the seedlings would lead to differences in yield, three types of seedlings from a pure-line bed, (1) strong and tillered, (2) strong but not tillered and (3) weak and not tillered were separated out and planted for comparison. The final yields of these three types were in the ratio of 143 : 112 : 100 respectively. Probably due to unfavourable rice season during the year of the trial, the results were a little exaggerated but still the experiment definitely proved that the condition of seedlings at planting time did affect the final results.

If seedlings of the tillered type used in the above experiment could be raised ordinarily it would greatly increase the crop, but the area of the seed-bed required would probably be prohibitive. It is by no means impracticable, however, to raise seedlings of the single strong type. The single weak type would compare favourably with seedlings ordinarily obtained by the ryots' method of cultivation.

In another experiment two seed rates, one measure and three measures per cent each, under manured and non-manured condition, were compared. Here the manuring of the seed-bed made no difference but the thinner sown bed gave over 10 per cent. higher yield than the thicker sown.

At the Samalkota station a number of seed rates was compared over a series of years, 1911–17, and the yield figures showed conclusively that the thinner the seed rate the better the resultant yield from such seedlings. The experiment was repeated in a modified form with two seed rates, thin, 300 lb. of seed and thick, 1,200 lb. of seed per acre of seed-bed with two varieties *palgum-masari*, an early one, and *konamani*, a late one, for four years consecutively from 1922–23 to 1925–26. The comparison of four years' results showed that thin sowing was always better. It also showed that an early variety gave better yields than a late variety when the seed rate was lowered. That early varieties respond better to thin sowing was also evident in an experiment conducted at Maruter where *basangi* gave a much better response to thin sowing than *atragada*. The increase in yield in the case of *basangi* was 14 per cent. while in the case of *atragada* it was only 6 per cent.

In connection with the second crop experiments at Maruter an attempt was made to find out the effect of sowing *garikasannavari* at two rates, thick (6 lb. of seed per cent), and thin (2 lb. of seed per cent), and at intervals of a week between early December and early January. The planting was done in every trial when seedlings were 35 days old. It was found that the thin sowing really did better only when the sowing and planting were done later. That the thin sowing did not show any response in the earlier plantings was due to the incidence of insect pests. There was also another advantage, though slight, in that the thin-sown plots always flowered a few days earlier than the thick sown.

In the advocacy of thin sowing, ryots often apprehend a shortage of seedlings as they are accustomed to plant the seedlings close. But if thin sowing could be combined with wider planting of the seedlings in the field, this difficulty could be obviated. To test this point an experiment was conducted at Maruter, where seed was sown at half the seed rate used by the cultivators and the seedlings were planted out at twice the distance adopted by them. It was found that the thin sowing and wider planting was better, the money value of the increased yield obtained together with the value of the seed saved being about Rs. 4 per acre. Another two rupees could be added to the figure as due to the savings in labour by adopting wide planting. This cannot, however, be taken as applicable to every locality. It is applicable only to soils of above average fertility as at Maruter.

In connection with the study of the different rates of sowing in seed-bed, one consideration that has to be kept in mind is the size of the grain. The rate considered as thin sowing in the case of *basangi* might really be thick in the case of *jeeragasamba*. It has been found by an experiment with a number of varieties, both coarse and fine, that usually the mortality of the seedlings in seed-beds was greater in the case of finer varieties and also when thicker seed rate was adopted. Comprehensive experiments are in progress at the Maruter station with different rates of sowing in the seed-bed for coarse and for fine varieties. It would appear possible to adjust the rate according to the size of the grain and the results already indicate that in the case of the fine varieties like *moshiapolo* the sowing rate can be very much below 2 lb. per cent of land.

(v) *Pulling and transplanting*.—When the seedlings are sufficiently grown they are pulled out for planting. Soon after the sowing of the seed-beds, the preparation of the transplant field is taken up and it gets ready by the time seedlings get sufficiently old. A day or two previous to the day of planting, the seed-beds are first flooded and the pulling starts. In the ideal seed-bed, the seedlings are not only well grown but they also come off easily. If the preparation of the seed-bed had not been thorough or if the land had been allowed to dry up frequently during the growth of

the seedlings, the pulling becomes hard, and unless very carefully done, the seedlings snap above the ground level and considerable wastage occurs.

The pulling of seedlings is done by both men and women. In Tanjore it is a special job for men and coolies are often specially engaged to pull out seedlings and are paid at either so much per cent of the seed-bed area or at so much per 100 bundles of seedlings pulled. The men actually squat in the water and do the pulling with both hands. When a sufficient number has been pulled out, the roots of the seedlings are beaten against a wooden stick to remove all mud particles that may be sticking to them. They are then tied into bundles, the leafy portion of some of the seedlings in the bundles, serving the purpose of string, by being bent down and taken round. The tied bundles are all of a standard size, the man including in each bundle enough to be held in both hands.

These bundles are then taken out of the water and left on the bunds to drain. They are then gathered, made into big headloads and carried by men to the place of planting. Where there is a water channel connecting the seed-bed and the transplant field, the bundles are strung together in a long coir rope and dragged along the water course. For distant places they may be carried in carts and boats.

In the case of dry seed-beds, under ideal conditions, pulling is very much easier and flooding the nursery before pulling may not be necessary. After they are pulled out and bundled they are left in a corner of the transplant field during the previous evening and planting is usually begun on the next day. The seedlings from the wet seed-bed may be left over for a day or two before planting.

How long can the pulled seedlings be kept?—In transplanting wet seedlings there is the question as to how soon they should be planted after they are pulled out. Pulling out the seedlings on one day and planting them the next day is almost the universal practice. But due to special reasons like heavy rain, a long distance through which the seedlings have to be carried and scarcity of labour, delay in planting will be inevitable. Provided the weather is ideal (cloudy weather without a hot sun), the seedlings establish themselves quickly but, if the weather is dry and hot at the time of planting, the seedlings establish at a much slower rate and in the latter case, the seedlings held over for a few days after pulling appear to fare badly.

In a small scale experiment at the Aduturai station, seedlings were pulled out and planted on the same day, second day, third day, etc., up to six days in a long duration variety, Adt. 2, and observations taken. The results disclosed that the transplanted seedlings did not establish themselves satisfactorily if planted later than the third or the fourth day but that the tillering capacity and yield of the established plants did not vary up to the fifth day. But in the sixth-day-planted crop, the establishment was

very poor, nearly 50 per cent. of the seedlings dying off, and the tillering capacity of the plants was also poor. This shows that there is absolutely no harm in delaying the planting up to three to five days after the seedlings are pulled out. This period however, is likely to be less for short duration varieties. Though no experiment has been done to test the point, the quickness with which the crop establishes itself is an important consideration in the case of early rices and as it is known that delay in transplanting after the seedlings are pulled out, delays establishment and increases casualties, the sooner the planting is done, the better. Experiments at Maruter with *garikasannavari*, a four months' crop, have also shown that it is not advisable to postpone planting beyond four or five days after the seedlings are pulled out. If delay in planting is likely to have an adverse effect on the crop even in the case of well-grown seedlings, this effect is sure to be more pronounced with the ryots' method of raising seedlings where the seedlings would be thin on account of thick sowing.

Ripening the seedlings before planting.—There obtains a practice in South Malabar, Palghat taluk, of purposely delaying planting and making the seedlings undergo a sort of ripening process for the second crop, planted in September-October. The seedling bundles are arranged in a circular heap with the roots exposed and all the green parts hidden inside. The heap is left undisturbed for three or four days. The seedlings on the fifth day are devoid of all green colour and look pale-yellow and are very flaccid. To regain turgidity before planting the bundles are left in water overnight in a corner of the field to be planted the next day. The chief idea underlying this practice is to encourage production of heat by fermentation and thus to destroy egg masses and young insects that the second crop is usually subject to in the tract. The temperature inside the heap of seedlings rises and if the heap gets dry for want of rain, water is also sprinkled on the heap to encourage fermentation. The seedlings treated this way regain their green colour after planting much faster than untreated seedlings and are on the whole better grown and freer from insect pests.

Experiments have been in progress at the Maruter station to adopt the above practice as a means of controlling mealy bug attack. Seedlings were ripened for a period of ten days and then planted. But probably due to the period of ripening, ten days, being much longer than necessary, the yield of the crop was not quite satisfactory. When next year a comparison of different periods of ripening, 4, 6, 8 and 10 days was made, rejecting all the dead seedlings, there was no difference in yield. The experiments definitely showed that this practice of ripening the seedlings for a few days before planting, not more than a week, has something to recommend as a sort of control measure against mealy bug attack in rice.

Pruning seedlings before planting.—Then there is the question of cutting off a portion of the foliage of the seedlings before planting. If the seedlings are a bit over-grown, a certain amount of top foliage is removed at the time of planting. By so doing the strain of transpiration on the plant which has to produce new roots and shoots is a little minimised. Moreover, if the seedlings are too tall, they may be easily blown over by the winds when the puddle is soft unless the seedlings are thrust well inside the mud which is not necessary. Experiments have shown that irrespective of the depth of planting, it is only the buds near the surface that get active and produce new shoots and there is no point in planting too deep. Probably there is no necessity to prune the seedlings at planting time as a general agricultural practice in all cases. It has got to be decided upon as circumstances necessitate according to the growth of the seedling. It is possible that excessive pruning might even prove disadvantageous if the level of the field is not ideal and the depth of water cannot be regulated. Ryots do not generally cut the tops of seedlings at planting time and there is a definite opinion expressed that it is harmful to early duration varieties. Experiments were conducted at Aduturai with two of the early strains, Adt. 3 and Adt. 4 ($3\frac{1}{2}$ months' duration) where the seedlings without any pruning were compared with pruning them to three inches and six inches height from top. In the case of Adt. 4, the cutting off made no difference in the final yields. In the case of Adt. 3, however, the yield was definitely reduced by the pruning of six inches of the height. It is probable that six inches was a little too much for this variety in relation to its actual height attained in the seed-bed. This experiment was carried out in a long duration variety Adt. 2 (6 months) and the pruning of the seedling did not bring on any difference in yield. Evidently the cutting has no effect in the late varieties. So long as it is known that the yield is not affected by a certain amount of cutting off the top of the seedlings at planting, the practice has something to recommend it in that it facilitates planting. At the Coimbatore Paddy Breeding Station, the practice of pruning the seedlings at the top is invariably practised as a convenience and there has been no ill-effect produced on the yield.

The pruning might also prove advantageous in that there is a possibility of getting rid of some of the insects, particularly thrips which, when present, are usually to be found at the tips of the leaves which remain rolled.

Number of seedlings planted per hole.—This has a direct bearing on the rate of sowing. With thin sowing of seed-beds resulting in strong seedlings, the tendency will be to plant fewer seedlings per hole. The ryots' practice has for a long time been to sow the seed thick and plant the seedlings in bunches which may contain anywhere about 10 to 15 seedlings. There have been observed certain instances where this number went up to even 30 or 40,

Time was when ryots used to plead that single or economic planting involved additional labour and extra costs as the women coolies who are engaged for this job were not trained to it. One seldom hears of this complaint now, and the coolies have got used to it in most places. Though the planting may not be actually in singles in every case, there is no doubt that due to the departmental propaganda, the number of seedlings planted per hole has been very much reduced in actual practice. They are now probably not more than three or four in a hole except probably in certain very backward tracts where the propaganda has not sufficiently spread. Though in earlier years the propaganda was for planting in singles it had to be modified into economic planting later on. Even in the experiments carried on at the Government stations, planting in singles has not been a uniform success, the results varying with the variety, locality, etc. As was pointed out already, even if the single planting or economic planting was just as good as bunch planting from the view point of yield, the saving in the quantity of seedlings required for planting and hence in the quantity of seed to be sown should be an important consideration.

In an experiment at the Aduturai station, the effect of increasing the number of plants per hole on the final yield was investigated, the variety under trial being a short duration 100 days' crop. Seedlings from two up to six per bunch were planted uniformly with six inches spacing and it was found that as the number of seedlings per bunch increased the yield per bunch also increased. The yield increase by planting five to six seedlings per hole was as much as 20 per cent. over planting only two per hole. Another experiment was conducted at this station for three years from 1926–27 to 1928–29, to assess the comparative merits of planting singles, doubles and trebles per hole in six varieties, two of the short duration and four of the long duration. In the case of the two short duration varieties, Adt. 3 and Adt. 4, there was a definite increase, 20 to 30 per cent., in yield with the increase in the number of seedlings planted per hole. In the case of all long duration varieties, however, there was absolutely nothing gained by increasing the number of seedlings.

In an analogous experiment conducted at the Palur station for a number of years it was found that in the case of varieties of over five months in duration there was no advantage in increasing the number of seedlings per hole beyond one or two. The results of earlier experiments at the Samalkota station with number of seedlings per hole for varieties like *konamani*, have led to the same conclusion that in the heavy delta land represented by Samalkota, with the small loss that occurs if planting takes place at the right time, it was sheer waste to plant more than one seedling to a hole. Again an experiment conducted at the Pattambi station with the variety *thavalakkannan* (about 4½ to 5 months in duration) for two seasons, proved the advantage of planting in singles or doubles over increasing the number of seedlings beyond two.

All the experimental results available so far go to show that with early varieties within four months' duration, it may be more advantageous to plant in twos or threes than in singles but there is nothing to be gained by adopting the same for varieties of five months' duration and more.

In connection with this study there is also another consideration which has to be examined. The ryots often contend that the yield of straw goes down by adopting economic planting. There is a good deal of truth in this contention as the figures obtained at the Aduturai station prove. In the case of the early varieties, with the increase in the number of seedlings per hole, there was a definite increase in the straw yield as well. In the case of the long duration varieties, however, such an increase was not apparent except in one variety. The straw yield does come into the economics of rice growing, particularly in places where a large number of cattle is maintained and there is no other fodder available. The straw question also arises in tracts where the land is cultivated by the tenant and where according to the lease terms he gets most of the straw produced. When as usually happens there is very little of grain left over to the tenant, he has to make something out of the straw he gets by selling it. Probably in several tracts particularly where cattle are not dependent on paddy straw alone this is not a serious matter and increased production of grain should be the main consideration. People in Godavari and Kistna would not mind foregoing a certain amount of straw if the grain yield of the crop should be satisfactory.

There is also another consideration with regard to the number of seedlings to be planted per hole, namely, the risk of casualties. In Madras in several of the rice tracts crabs do much damage to young seedlings soon after they are planted out and if the plants are put in singly there are greater risks of gaps occurring with such damage.

Studies on inter-relationship between spacing allowed between plants at planting time and the number of plants put in per hole always show that spacing has a greater effect in the number of tillers produced and on the length of the earhead formed than the number of plants per hole. In early varieties irrespective of the number of ears and the length of ears, it is the total number of plants planted per unit area that influence the total yield. The aim of the experimenter is to get the maximum outturn per unit area. For a given area the same number of plants may be planted in two different ways: (1) by increasing the area between holes and increasing the number of plants per hole or (2) by reducing the area between holes and reducing the number of plants per hole. It is in the right choice of either of the above methods that the success of the agronomic practice will depend. The experimental results would appear to show that it is a better

practice to reduce the number of plants per hole and plant them closer in the case of early varieties; in the case of long duration varieties the optimum spacing suitable to the particular condition must be determined and no serious attention need be paid to the number of seedlings per hole, and even here the fewer the seedlings per hole the better. This takes us on to the consideration of the next problem, namely, the optimum spacing to be allowed for planting rice seedlings.

The spacing between plants.—This has formed the subject of investigation for a number of years at all agricultural stations. Probably no other agronomic practice influences the development of the plant and the final yield as spacing does. The optimum spacing to be adopted will depend upon several other conditions, the most important of them being the variety and the fertility of the land. An early variety or one that is inherently poor in tillering has got to be planted closer than a later one or an inherently good one for tillering. So also in a fertile land in good condition the planting may have to be wider to avoid the risk of too much vegetative growth and premature lodging whereas, in a poor land, the planting will have to be closer. The effect of season on the development of the plant is well recognized. Planting early in the season compensates to a large extent the deficiency in fertility of the land as in Godavari delta and if the planting is delayed unavoidably the only way of counteracting the evil effects of the later season is to plant the seedlings closer. Similarly well grown strong seedlings can be planted wider than poor weak seedlings. The recognition of the interactions of the various factors and adjusting this important agronomical practice accordingly, helps in a great way the successful raising of a rice crop.

The results of a number of spacing experiments conducted at the agricultural stations will be discussed here. In the earlier years, prior to 1920, the most comprehensive experiments on spacing are those conducted at the two stations, Samalkota and the Central Farm, Coimbatore. Though even these experiments might be taken as not correctly laid out with suitable replications to give valid results from considerations of modern experimental technique, yet the results obtained give an indication and emphasize the complicated nature of the problem.

At the Coimbatore Farm, the experiment was conducted for eight years consecutively with two local varieties, *sadaisamba* and *chinnasamba*, the former being coarser and earlier by about a fortnight than the latter. The spacings compared were singles in 4″, 6″ and 9″; doubles in 9″; and trebles in 9″ and 12″ against the local ryots' method of planting. Comparing the average results of all the eight years it was shown that in none of the spacings was the yield of grain definitely better than the local method of planting with regard to *sadaisamba* except probably trebles 12″. The straw yield was, however, definitely poorer than the locals

in all the plantings. In the case of *chinnasamba* however, both the yields of grain and straw were definitely better than the local, and better than either 4″ or 9″.

The Samalkota experiment was concerned with two varieties *rasangi*, a quick growing coarser variety and *konamani*, a longer term rice of better quality. The treatments compared were singles in 4″, 6″ and 9″ and doubles in 4″, 6″ and 9″. Unlike the Coimbatore experiment, the treatments were sufficiently replicated and hence the results might be taken as reliable. The yield figures showed that the wider spacing, 9″, was in all cases too wide, though the reduction in yield due to the 9″ spacing was less in the case of *konamani* than in *rasangi*. If two seedlings were used instead of one, an increase was obtained in *rasangi* though not in *konamani*. One rather unusual result emanating from this experiment was that the straw yield was increasingly better as the spacing increased, 9″ being better than 6″, and 6″ being better than 4″. The figures indicated that 4″ was about the optimum for *rasangi* and somewhere between 4″ and 9″ for *konamani*. To test the relation between spacing and the fertility of the land, during the last three years of the experiment, the different plantings were duplicated in manured and unmanured fields. It was found that the yields of the wider spacings increased in the manured plot indicating that the optimum spacing may be higher than 4″ and 6″ for *rasangi* and *konamani* respectively in a fertilized field. The experiments both at Samalkota and Coimbatore clearly indicated that the optimum spacing depended upon (1) the variety of rice concerned, and (2) the fertility of the land either natural or added.

Experiments on modern lines with replications have been conducted in later years on the question of spacing for rice planting and the results are discussed below.

At the Aduturai station six spacings of 3″ × 3″, 4″ × 4″, 6″ × 6″, 8″ × 8″, 6″ × 1′ and 1′ × 1′ were compared in a short duration variety of 100 days, planting being two seedlings to a hole. It was found that the yield per plant steadily increased as the spacing increased so much so that the plant with the spacing 1′ × 1′ gave nine times the yield of a plant with 3″ × 3″. This increase in yield was brought about by increase in both the number of ears per plant, and number of grains per ear. Though the yield per plant increases with increased spacings, the number of plants per unit area gets less and less, the reduction being even in a greater proportion than the yield; for example the yield of a plant in 4″ × 4″ plot is 1/9th of the yield of the plant in 1′ × 1′ plot but there are 13 times as many plants in the former as in the latter. Since the total yield of a plot is the multiple of the number of plants and the yield per plant, the increase in yield per plant does not sufficiently compensate for the reduction in the number of plants. Consequently when the total yields

of the plots are compared it is found that it goes down lower and lower as the spacing increases and the highest yields are obtained with 3″ × 3″. The experiment definitely proved that it was not economical to adopt any spacing wider than 3″ × 3″ for this short duration variety.

An experiment conducted at the Maruter station with three short duration varieties, all within 110 days' duration, and with three spacings, 4″ × 4″, 7½″ × 7½″ and 1′ × 1′ also bore out the results of Aduturai in that the closest spacing, 4″ × 4″, gave the highest yield.

A spacing experiment has been conducted with the variety *bayyahunda* of five months' duration at the Berhampur station for three years. The spacings adopted were 3″ × 3″, 6″ × 6″ and 10″ × 10″. While the general characteristics of the effect of increased spacing on larger number of ears and longer panicles per plant were apparent, the total yield was definitely against the wider spacing of 10″ × 10″. There was practically no difference in yield between 3″ × 3″ and 6″ × 6″ which means that up to 6″ the increased production of tillers compensates for the reduction in the number of plants planted. It therefore follows that 6″ is about the optimum spacing for the variety under the conditions obtaining at Berhampur. In the same experiment the interaction of manures by the application of 150 lb. of ammo-phos per acre at planting time was investigated on the different spacings. While the effect of the manure was generally significant, it did not influence differently the different spacings. Even here 10″ was the poorest and there was no difference between 3″ and 6″.

A similar experiment has been conducted at the Pattambi station with two first crop varieties (June to September) *aryan* and *thavalakkannan* of about 4½ months' duration. Four spacings had been adopted, 3″ × 3″, 6″ × 6″, 9″ × 9″ and 12″ × 12″. The results showed that there was not much difference in yield between the different spacings but 12″ × 12″ appeared to be definitely too wide. The same experiment repeated with a second crop variety (September to January) Ptb. 3 of the same duration, definitely showed that there was no difference between 3 inches and 6 inches and there was a tendency for the yield to go down with 9 inches and it was definitely bad with 12 inches. The soils of Ganjam and South Malabar are generally poor compared to the deltas and for such poor soils even for varieties of five months' duration it is not economical to adopt any spacing wider than 6 inches.

Let us now compare the above results with those obtained at Maruter for varieties of similar and of longer duration. The soils at this centre must be considered much more fertile than at Berhampur or Pattambi. In one of the trials with varieties *akkullu* and *krishnakatukkullu*, the yields were the same for two spacings of 6″ × 6″ and 6″ × 12″ proving that the optimum must be more than 6″ × 6″.

A comprehensive experiment was conducted at the Paddy Breeding Station, Coimbatore, involving spacing and manuring for two varieties, one of five months' and the other of six months' duration. In the beginning only three spacings of 3″ × 3″, 6″ × 6″ and 12″ × 12″ were adopted and as in Berhampur the yield per unit area was the greatest in 3-inch spacing and there was only a very small difference between 3 inches and 6 inches. The 12-inch spacing was definitely too wide. Later the 12-inch spacing was dropped but three more intermediate spacings, namely, 4½ inches, 7½ inches and 9 inches were introduced and the experiment repeated for two more seasons.

The general trend of the results is that the optimum spacing for the five months' variety is between 4½ and 6 inches, the total yield being the highest in these two spacings. The yields are definitely less in the case of 3 and 7½ inches. In the case of the six months' variety the maximum yield is with 4½ inches. While both wider spacing and manuring increase the yield by improving the number and length of ears, the former has apparently a greater effect than the latter. There was no apparent differential effect of the manure in the different spacings. The results are interesting in that though the average yields of Coimbatore are very much higher than in Berhampur or Pattambi the optimum spacing for the long duration varieties appears to be very nearly the same, namely, within six inches. With regard to Maruter, however, it appears to be definitely more. Varieties of rice do not tiller so freely in Coimbatore as in Maruter and to get the maximum yields the spacing evidently should not be more than six inches.

The general trend of the results from the various spacing experiments would appear to be that it is not possible to lay down that such and such a spacing is the optimum. It will have to vary according to the variety and fertility of the soil, and can be determined only by actual experiments at the particular centres. While the varietal and soil fertility differences are apparent with regard to different spacings, the fairly uniform results obtained from year to year at every centre of experiment for particular spacings would show that the season has apparently no influence on spacing.

Age of seedlings.—The period for which the seedlings must be allowed to remain in the seed-bed varies with varieties, fertility of the seed-beds and with the manner of preparing the seed-beds. The general accepted principle is that for short duration varieties, the seed-bed period should be short and for long duration varieties it could be longer. Roughly a week is allowed in the seed-bed for every month's duration of the crop; this applies to the wet seed-bed. In the case of the dry or moist seed-beds, however, because of the comparative slower growth, the seedlings might be allowed to remain in the seed-bed longer than the time-limit allowed.

In addition to the age, the condition of the seedlings in the seed-beds is another criterion for planting out. From the ryots' point of view, more than the age, it is the commencement of the formation of nodes in plants even in the seed-bed that makes the seedlings unfit for planting. So long as sowing is thin and there is sufficient room for plants to develop tillers without formation of nodes, the age of the seedling does not affect the crop obtained. For short duration varieties of less than three to four months, the seedlings can be planted out even earlier than three weeks provided the growth is satisfactory. In Tanjore delta the nurseries for the first *kar* crop are prepared in tank-beds or in the most fertile portion of the area adjacent to village-sites and the seedlings grow even a foot high by about 15 or 17 days and they can be planted out then. The only consideration in planting seedlings too young is the careful watering of the transplant field for a few days until the seedlings establish themselves. Flooding may have to be avoided and the damage due to crabs is likely to be a problem to fight against. The earlier the age of the seedling, the sooner it is expected to establish itself. Getting the seedlings established in the field as early in the season as possible is one of the important desiderata for a successful crop. Sometimes planting the seedlings too young but with the necessary growth in the case of long duration varieties, results in too rank a growth of the crop and premature lodging. Sometimes when the season is late, i.e., when water for the preparation of the nursery is received late all attempts should be made to hasten up the growth of the seedlings and plant them out early. Under such circumstances resource is usually taken to apply a small quantity of ammonium sulphate, about 50 to 100 lb. per acre of seed-bed area to force up the seedlings.

Apart from any special conditions described above we should have some idea as to the optimum age at which the seedlings should be transplanted. This applies only to the *samba* or *sarva* varieties mostly, as in the case of early *kar* varieties the principle that the sooner it is done the better, is well established and recognized in practice. The necessary information with regard to the optimum age will have to be determined by actual experiments in the different rice tracts. This has been receiving attention practically at every agricultural station even from very early days. In any experiment to determine the comparative merits of seedlings of different ages, there are two ways of carrying it out. One is, to sow the seed-beds all in one day and transplant the seedlings on different dates according to the requirements of the experiment and the other is, to sow the seed-beds on different dates and do the transplanting all in one day with the seedlings of different ages. It cannot be said definitely whether the results are likely to be different when either of the above method is followed, but this point is receiving attention in the recent experiments in progress at the several rice research stations. From the experimental

point of view, when the planting has to be done on different dates, the question of the preparation of portions of the fields for transplanting does involve practical difficulties with irrigation and weeding. From this point of view, preparing nurseries on different dates and transplanting them all together is certainly more convenient but this is a question at present resting solely on the convenience and facilities available to the experimenter.

One of the earliest of experiments on this subject was that done at the Samalkota station between the years 1908 and 1914. Three ages of seedlings were under comparison for the *sarva* crop, namely 25, 35 and 45 days. During half the number of years the seed was sown on the same date and transplanting was done on different dates, and in the other half, the planting was all done on one day, the sowings being on different dates. The average yield of grain per acre for all the years worked out to be, 3,475 lb., 3,340 lb., and 3,404 lb., for the 45, 35 and 25 days seedlings, respectively. Since the differences between these figures were within the limits of error it was concluded that it was a matter of small moment whether the seedlings were 25, 35 or 45 days old so far as grain yield was considered. A point of general observation in this experiment was that the oldest seedlings always took longer to establish themselves and always suffered more from casualties.

In an earlier experiment at the Palur station, seedlings of 30, 40 and 50 days old were compared for a six months' *samba* crop and it was found that the yields were practically the same in all the cases. It was observed, however, that early tillering was more in the younger seedlings than in the older ones.

This subject was investigated even at the Central Farm (Coimbatore) wet lands as early as 1908–09 to 1910–11. The experimental results were not reliable as the land used for the experiment was not ideally situated and it also suffered from patches of alkalinity. Durations of 25 to 40 days with five days interval, were compared in the local variety *sadaisamba* of 5½ months' duration. Incidentally different rates of sowing of seed-bed in one year and different plantings, bunches and singles in another year were combined with ages of seedlings. Where the seedlings had been sown thick according to the ryots' method there was no indication of any difference in yield among the different ages but where the seed-beds had been sown thin, the indications were that younger seedlings did better than older ones. This is probably what one would expect, because in the thick sowing the growth of seedlings must have been retarded and the young seedlings when planted could not show any advantage, whereas in the thin sowing, the seedlings would have attained the plantable stage earlier and with the accepted principle, the earlier the planting the better the yield, it should have done well. Where different methods of planting had been adopted the bunch planting did not show any

difference among the different ages of seedlings but the single planting gave an indication that the optimum age was about 30 to 35 days. Since, however, the plots planted with seedlings of 20 and 25 days suffered from gaps, much reliance could not be placed on this indication.

Experiments relating to this subject have been carried on recently adopting the modern methods of experimental technique at the rice stations, Coimbatore, Aduturai, Pattambi and Berhampur and the results obtained are given below.

Coimbatore.—In 1932–33 seedlings of five ages 25 to 53 days with a week's interval between two ages were planted for comparison, the variety being Co. 5, a five months' crop. Apart from the indication that the 39 days old seedlings might be the best, the yield differences among the different ages did not warrant any definite conclusion. Observations on the crop showed that though there was considerable difference in tillering in the differently aged plants in the early stages, they all levelled up as the plants got older. This experiment was repeated next year with modifications introducing greater differences in ages. There were four ages 25, 40, 55 and 70 days. The experiment was arranged in two series, one where the sowing was done on one day, and planted on different dates according to ages and the other, where planting was done on the same day, sowings having been done on different dates to get the right ages. Another modification was also introduced in that, half the seed-bed area was manured with cattle manure, leaving the other half without any manure. Even in this year there were no definite differences in yield among the different ages or between the manured or non-manured seedlings. It did not matter how the planting was done, on different dates according to ages or on the same date according to the different sowings. The crop of the latter was, however, looking more healthy and yielded a bigger gross grain produce than the former. From the results of this experiment it would appear as if there is no differential effect produced in the crop by planting seedlings of different ages from 25 to 70 days under Coimbatore conditions. But it was noticed, that even in the 70 days old seedlings, there was no indication of the formation of nodes and the seedlings were quite healthy.

There was one interesting observation that emerged out of this experiment. Where the differently aged seedlings were all planted on the same date there was no difference in the flowering period, but where the planting was done on different dates, the earlier the planting the earlier was the flowering. It is evident from this that it is the time of planting and not the age of the seedlings that has the greatest influence on flowering.

Aduturai.—A preliminary experiment conducted with *nellore samba*, a six months' crop, with seedlings age 3, 4, 5, 6 and

7 weeks, there was an indication that the yields were likely to be the same between the ages of three weeks and six weeks, the yields, however, going down beyond six weeks.

Berhampur.—Experiments have been carried out for three seasons with ages, 30, 40, 50 and 60 days in the variety *bayya-hunda*, a five months' crop. There was a remarkable similarity in all the three years' results. There was no significant difference in yield among ages 30 to 50 days but the yield definitely dropped beyond 50 days. It is certain that under conditions obtaining in Berhampur there can be no harm resulting from planting seedlings up to 50 days of age. As in Coimbatore, the Berhampur results also showed no difference between planting on the same date or planting on different dates.

Pattambi.—At Pattambi station, an experiment analogous to the one at Berhampur was conducted with the same ages in a second crop variety, Ptb. 3 of five months' duration, and it was found that seedlings could be planted up to 50 days, there being no difference among 30 to 50 days. In the case of very early sown nurseries, planting aged seedlings up to 50 days seemed to be preferable to planting early with short ages. Just as in spacing, the conditions obtaining at Pattambi and Berhampur appear to be more or less similar.

(vi) *Season for sowing and planting.*—The time of sowing and transplanting has got a great influence on the behaviour of the crop. Varieties of rice change their characteristics, often completely when they are moved from one tract to another with different climatic conditions or when it is grown in a season other than the usual. Apart from growth and final yield, the one characteristic which is particularly affected by such changes is the duration or life period. Some varieties become shorter in duration and others longer. Among the rices two broad groups may be recognized, (1) those which are time-limited and (2) those which are season-limited. Time-limited varieties are those which irrespective of when they are sown or transplanted take more or less the same period to come to harvest. Season-limited varieties are those which irrespective of when they are grown come to maturity at a particular season of the year changing their life periods either by extension or reduction. Most of the *kar* varieties like *kuruvai* of Tanjore, *kar* of Tinnevelly, *sornavari* of Trichinopoly and South Arcot, *garikasannavari* of the Godavari, etc., all belong to the first group. A large number of short duration varieties of three to four months' duration available in the Coimbatore collections has been tested for this characteristic and while most of them kept to their short duration even when grown out of the normal season, there were a few which did change their normal age and appeared longer. The yields of course differ considerably and they are far less in out-of-season crops.

Effect of season on duration.—Instances of varieties changing their duration when removed from one place to another and by planting them in different seasons have been many. The *kayama* rice of North Malabar which is usually sown in the nursery in April-May, when taken to the East Coast of the Province and sown in the nursery in June-July, ripened at the same season that it would have done in its own home, i.e., September-October. In addition, while it generally does not produce more than four or five side shoots in its home in Malabar, formed more than eight or ten side shoots in the East Coast. The *konamani* of the Godavari district is a five to six months' crop. It is planted there in June-July and harvested in October-November. When this is tried in Coimbatore where planting is done in August-September it becomes shorter in duration and ripens in a little more than four months. *Banku* is a variety of rice introduced into Madras from the Central Provinces. It is a four months' crop and does well in two seasons either when planted in June-July or October-November. If, however, it is planted in March-April its life period is prolonged and does not mature until October, similar to the crop planted in June-July.

In contrast to the above instances, there are several others where varieties when moved from one tract into another have not changed and have proved satisfactory even though the conditions of rice growing might be different in the tracts concerned. As examples of such cases might be mentioned the *nellore samba*, first introduced from Nellore into Tanjore and which has later spread in most of the Tamil tracts, and *poombalai* of Tinnevelly, first introduced from Tinnevelly, and which has spread over several other tracts.

Among the departmental strains, GEB. 24, is a noted example of season-limited rice. Some years ago when it was first taken to Madura by an enterprising ryot and planted in August-September it gave satisfactory results ripening off in December-January. The ryot was very much impressed with its performance and he planted it again as a second crop in January as he had facilities for irrigation. Instead of coming to harvest in four months as he expected it would, the crop continued to grow on without producing ears until next September-October. This strain is now grown extensively all over the Province under varied systems of cropping. Its duration varies according to the time of planting. At Coimbatore, it is normally planted in July-August and harvested in December, taking 4½ to 5 months to mature and gives satisfactory yields. It is grown extensively in parts of Godavari where the planting time is earlier, i.e., June-July and there it takes six months to attain maturity, coming to harvest at the same time as in Coimbatore. In parts of Malabar when it was tried as a first crop, planted in May-June, it proved a failure because it did not ripen off along with the local varieties in 4½ months and by remaining alone in the tract became subject

to all insect pests. It has, however, fitted in for the second-crop season of Malabar and South Kanara where it is planted in October-November and harvested in January-February.

Relation between duration and yield.—It must, however, be understood that the total yield more or less goes with the period of maturity. Maximum yields are obtained only when it is planted early enough and the ripening period is not less than five months. As the period of ripening is reduced by later plantings the yield also goes down. That it is still cultivated as a late crop in certain parts of the Province is due to the fact that in spite of its relatively poor yield resulting from such late planting it compares favourably with the local varieties.

Co. 2 and Co. 3, two other strains evolved at Coimbatore, take 5 to 5½ months under Coimbatore conditions when planted in July-August. They were first tried in parts of Guntur district but had to be given up since, due to the earlier planting, they were slightly longer in duration than the local varieties. They do not seem to suffer very much by late planting though their duration might get reduced by such a practice. They have fitted in in the cropping of South Kanara where, planted as a second crop in October-November, they ripen off in January-February giving satisfactory yields.

That a variety manages to adjust itself to changed conditions of planting without considerable fall in yield is always a very desirable characteristic. Several of the good Godavari varieties, *akkullu*, *krishnakatukkullu*, *konamani*, etc., do not prove successful in the Tamil districts because of the later plantings obtaining here as compared to Godavari.

In the Tanjore district there are both single crop and double crop lands. While the former is planted in August-September, the latter cannot be done before October as the land has to be prepared after the harvest of the first *kuruvai* crop. The *sirumani* varieties do well in single crop lands but not as a second crop in the double crop lands whereas, *nellore samba* is grown both in the single and double crop areas. Though its yield as a second crop is not quite as satisfactory as the first crop it does better than *sirumani*. *Basangi*, the early first crop of the West Godavari, is a very heavy yielder when planted early but seldom does well when planting is delayed.

Effect of season on yield.—In Godavari the time of planting is a very important criterion for the success of the crop and this is found reflected in the average acre yields obtained in the different parts of the delta. Wherever planting can be done immediately after the opening of the canal in June, greater yields are recorded. The Western delta which gets its water-supply earlier, records higher yields, generally, than the Central or the Eastern delta.

There is always a rush to expedite transplanting and often exorbitant wages are paid at this time. Similarly in Tanjore the sooner the first *kuruvai* crop is planted the better is the yield. In the upper portions of the Cauvery delta where water is received early and planting can be done early, better yields are recorded than in the lower portions.

As early as 1914, an experiment was conducted at the Samalkota station to test the truth about the fall in yield due to late planting. In that year the planting was begun on the 15th of July and was continued at intervals of one week until eleven different transplantations had been done. A long term variety of rice, *konamani*, was used in the experiment. It was obvious from the results that the later transplantations were unnecessary as the low yields obtained from those plots practically amounted to failure of the crop. In the following year the number of plantings was cut down to four, at intervals of a fortnight beginning on July 11th, and a shorter termed variety *sannaatragada* was experimented with. The results again showed a low yield in the case of the later plantings. Next year it was considered that some of the loss due to late planting might be made up if the seedlings were planted closer together, and if the land was manured. Accordingly half the plots of the two latest plantings with three varieties of different durations, *rasangi* a short term rice, *sannaatragada*, a medium duration rice, and *konamani*, a long term rice, were manured. Plantings began on 7th July and continued at intervals of a fortnight. The experiment was repeated the next year. The results showed conclusively that once the proper season for planting was lost the yield was bound to fall. The yield of grain was about 5,000 lb. per acre for the first planting in 15th July and it gradually went down and reached a level of about 1,300 lb. for the planting in 23rd September. Even the manuring did not have any material effect on improving the yield for the later plantings.

Certain experiments have been conducted both at Coimbatore and at Aduturai to determine the effect of planting some of the strains at different times of the year. At Coimbatore strains GEB. 24 and Co. 3 have been sown at intervals of a month beginning with June and planted out under uniform conditions in the fields up to next February. Observations were taken of every planted crop regarding tillering, height of plant, duration of the crop, size of the panicles, occurrence of sterile spikelets and finally the yield of grain. The experiment continued for five years from 1925–26 to 1929–30.

GEB. 24.—Taking the results of all the years together it might be stated that GEB. 24 sown in any of the months, July to September, would give normal yields. October and November yields were very varying, November sowing giving average yields in some years and rather poor yields in others. There was,

however, a definite drop in yields in sowings later than November. January sowing was about the poorest and February sowings have in some years given good yields but the duration of this crop was so prolonged that it would not be worth the trial.

As regards the flowering duration it was observed that it was definitely shortened as sowings became later up to a limit in October when it rose again and became abnormally long with January and February sowings.

Co. 3.—With regard to this strain the results were very dissimilar to GEB. 24. The early sowings in July and August gave high yields and there was a definite fall in September sowings in all the years. Except in one year, the October sowing was poorer still and so was November. There was a slight recovery in yield in December sowings and January and February sowings were the poorest of the lot.

As regards the flowering duration the results were more regular than in GEB. 24. There was a regular fall up to October and then a rise, becoming abnormal again for the February sowings.

Generally there was a characteristic higher percentage of unsetting with late sowings, but in this connexion the incidence of insect pests which is usually high in any crop grown out of the season must be taken into account. On the whole the experiment showed that with GEB. 24 to get a satisfactory crop under Coimbatore conditions, it should not be sown later than September; with regard to Co. 3, however, there was a clear indication that to get the maximum outturn it should be sown as early as possible, in the season, the sooner the better.

A similar experiment was carried on with the two *kuruvai* strains, Adt. 3 and Adt. 4, at the Aduturai station for two years, 1926–27 and 1927–28. There were eight sowings in all with a fortnight's interval between two, beginning with middle of July, the normal time adopted in the tract and ending with the last week of October. The results were almost like those obtained for the first crop trial at Samalkota mentioned earlier. As the sowings got delayed the duration of the crop slightly decreased and the yield also went down very rapidly. The yields of September sown crops were hardly 50 per cent. of those obtained in July sowings.

All the above experiments point out unmistakably that for satisfactory crops the sowing should be done early in the season. This principle applies equally to both short duration and long duration crops. There may be some varieties of rice, however, like GEB. 24, that have a fairly wide period, sowings within which do not materially affect the yields, but this probably is more an exception than a rule. While the adjustment of cultural practices as fertilizing the crop, planting the seedlings closer, etc., might to a certain extent obviate the harmful effects of lateness in sowings, they can never replace the good effects of early sowings.

(vii) *Broadcasting versus transplanting rice crop.*—The advantages of transplanting over broadcasting and the special conditions under which the latter is in vogue have already been mentioned. Broadcasting is confined to tracts where the water availability is uncertain and the season is not always dependable. It is usually adopted more in the short duration rices than in the long duration ones. Transplanting is the normal practice obtaining over the larger part of the area under irrigated rice. It would be safer to say, that four-fifths of the rice grown in the world is transplanted, and almost all countries like Spain, Italy, Japan, etc., where the highest acre yields are recorded adopt transplanting. Drilling the crop is to a certain extent replacing the practice of transplanting owing to labour difficulties as in California. In Italy where also labour is expensive they are attempting to evolve a satisfactory transplanting machine which can be worked in the puddle. The fact that the yield per acre is increased by transplanting is well recognized though, however, the reason for the increase has not been satisfactorily explained by experimental evidence.

It has been sometimes explained that transplanting acts in a way like root pruning, the injury to the root system stimulating the growth of the sub-aerial portion and resulting in increased tillering. It is also stated that transplanting gives a shock to the plant which stimulates better growth and better tillering and consequently better yield. This shock theory cannot, however, be accepted since seeds directly dibbled in lines, yield very much higher than even the transplanted crop.

In one of the earlier years a small experiment was conducted to compare actual dibbling of sprouted seeds in the field with transplanting of the seedlings. Two varieties of different durations were under trial in this experiment and in both cases the dibbling proved very much superior to transplanting from the point of view of plant's growth and final yields. In both Adt. 3, a 100 days' crop and in GEB. 24, a five months' crop, the dibbled plots gave as much as twice the yield of the transplanted plots. Similar results have been obtained in other parts of India and even outside India. If this dibbling of seed can be adopted on a field scale there is no doubt that the increase in yield that might be obtained should be enormous. Drilling though very much similar to dibbling is done under dry conditions. Dibbling in puddle is what should be aimed at. Further experiments may have to be undertaken about this aspect of the matter.

It is possible that the following explanation which is purely physiological might account for the better performance of the transplanted crop over the broadcast. When the crop is broadcast in the field the seed is usually sown thick so that there is overcrowding of plants resulting in competition among them; the more the plants per unit area, the less must be the food

absorbed by them from the field. In addition to competition for food material there may be competition for light also when plants are crowded and such a competition is likely to affect early tillering and number of ears, and also encourage shoot growth at the expense of root growth. There have been observed striking differences in the relative development of the root system between the transplanted and the broadcast crop. Even when sufficient space is allowed by thinning out the broadcast crop it does not develop a strong root system. It would appear that plants require plenty of space in the early stages to develop a good root system. But under certain conditions, a good season being probably one of them, broadcasting is found to be as good as transplanting.

There have been several experiments conducted in the different agricultural stations to compare broadcasting with transplanting. In connection with the second crop trials for the Godavari delta, experiments were arranged to find out (1) the optimum time of sowing the crop and (2) to see which would be better, either transplanting or broadcasting. The results showed that for early sowings in December, transplanting was just as good as or slightly better than broadcasting whereas for later sowings in January, broadcasting was distinctly better than transplanting.

At Coimbatore, comparisons have been made between broadcasting and transplanting for three varieties of varying durations. In all the trials transplanting was distinctly better than broadcasting. In the experiments regular plots were prepared under uniform conditions and in one set the seed was sown direct. For the other set seedlings from a separate seed-bed sown the same day were later transplanted. At the time of transplanting, the broadcast plots were weeded and the crop thinned out and gaps filled in, this being done in such a manner as to give nearly the same number of plants per unit area as in the transplanted crop. The increases in yield due to transplanting were 37 per cent. in *kar* (four months), 27 per cent. in Co. 1 (five months) and 42 per cent. in Co. 8 (six months).

A scrutiny of the yield data showed that in spite of the larger number of ears in the broadcast plot, the greater length of ears and the larger number of grains per ear have contributed to a heavier crop in the transplanted crop. Calculation of cost showed that there was a clear extra profit of Rs. 8–8–0 in *kar*, Rs. 14 in Co. 1 and Rs. 18–8–0 in Co. 8 over the respective broadcast crops.

There is also one difficulty with broadcasting which it would be worthwhile to remember. Sometimes the young rice plants soon after they are sown become subject to the attack of thrips and suffer badly. When this affection occurs in the seed-bed, it is easily controlled by either flooding the seed-bed or spraying with tobacco infusion. The adoption of remedial measures on a field scale, when

the crop is broadcast would, in most cases, be impossible to attempt. In one of the seasons this experiment had to be abandoned due to this thrip attack in the broadcast crop.

Besides the thrips, in parts of North Malabar and South Kanara, in some seasons the crop becomes subject to a serious attack of rice hispa. Generally for the second crop which is grown here between November-February either broadcasting or transplanting is adopted. When the attack becomes severe there is always a possibility of checking it by adopting control measures in the seed-beds but when the attack is in the open broadcast field, the ryot is helpless.

In a trial at Pattambi, with variety *thavalakkannan*, in the first crop season, June to October, transplanting gave nearly 20 per cent. more yield than the broadcast crop.

In northern parts of Ganjam district there obtains the practice of broadcasting even in portions of the area fed by canals. Fields transplanted one season are broadcast the next season. The ryots there are usually of the opinion that a well managed broadcast crop would yield just as well as a transplanted one. An experiment was started to test this point at the Berhampur station. In the broadcast plots half the area was thinned out by actually ploughing the soil when the crop was about a month old and in the other half the thinning was done by hand. Two years' results have been obtained and they go to show that there is no difference in yield between the two practices. It must be remembered that the rice season of this tract was favourable in both the years. The ideal condition required for a broadcast crop are good early showers, facilitating a thorough preparation of the land, and timely rains to get in the crop in the right time. These conditions were fortunately satisfied in both the seasons. It may therefore be said under the conditions obtaining here that in good years, broadcasting is just as good as transplanting. But generally the broadcast crops suffer more from precarious weather conditions and it is seldom that an ideal broadcast crop is met with.

Observations made on the root systems in the two cases both at Coimbatore and at Berhampur showed that in the broadcast crop the maximum length of the bigger roots was shorter and the finer roots fewer in number, thinner and shorter than the corresponding ones in the transplanted crop. It is probably due to the differences in the root system that the broadcast crop is often found to lodge much more than a transplanted crop, there being no sufficient anchorage in the soil.

There is in some parts of Madras as in the Salem district, a combined practice of broadcasting and transplanting. The fields are first sown and when the crop is about a month to six weeks old the whole crop is ploughed up and the field levelled and the seedlings moved by the plough are transplanted evenly. There does not appear to be any special advantage to recommend this practice.

CANAL IRRIGATION IN GODAVARI DISTRICT.

A VIEW OF THE PADDY BREEDING STATION, COIMBATORE

While all the field operations up to planting are attended to by the cultivator himself, labour has to be engaged for planting. This is exclusively done by women coolies. In the deltas, where a large area has to be transplanted in as short a period as possible, there is usually scarcity of labour and often high wages have to be paid. Wages for transplanting may be as high as eight to ten annas per head per day which is about twice or thrice the normal rate. Usually there is migration of coolies from the dry tract to the deltas during this period and the planting is all done by them on contract.

(viii) *After cultivation—Irrigation and drainage.*—There is no hard and fast rule with regard to the method of irrigation. In the case of swamp rice when once the flooding of the fields has commenced it is generally recognized that the field should not be allowed to crack and dry out until the grain commences to ripen. After the transplanting is over, the field is usually kept drained for some time to hasten the seedlings striking root. When the seedlings are established, water is let into the field and kept there, the only precaution necessary being not to let in too much of water to drown the crop. Most of the rices can stand a certain amount of submersion provided it is not continued too long. In certain tracts without proper facilities for drainage, fields do remain submerged for some days during certain seasons, specially on the east coast when the north-east monsoon happens to be very heavy. The water once let in will have to be changed but the frequency of change will largely depend upon the supply. Generally, ryots will like to change the water as often as possible because of the silt which is brought down with the water. This silt deposited in the field adds to the fertility of the soil. Besides the silt there is also the advantage of aeration to the roots. Though rice may be grown under swamp conditions, its root development is greatly influenced by aeration which is brought about by frequent change of the irrigation water. Well-drained land may not require too frequent a change but heavy and badly drained land and land inclined to be alkaline do require the water to be changed frequently. The necessity for this can be easily recognized by the examination of the root system. In a well-drained land the root is found to go down to a depth of a foot or 14 inches whereas in an alkaline land it is practically confined to a few inches from the surface.

Though in India it is considered essential to keep the water always in the field throughout the growth of the crop, in some of the other countries like Italy, Spain or America, there is often a practice to drain the water off completely from the fields now and then; this practice is supposed to make the plants grow more vigorous. It looks as if rice can stand this treatment without any harmful effect. In some years due to adverse season and rather limited supply of water there is no possibility of keeping water always in the field. Provided this does not occur too often or too

long to make the soils crack, there is apparently no damage done to the crop. This draining off can be done only before the plants start forming ears. When once the plants enter this phase, water must be supplied in plenty as this is the period when the transpiring activity is most intense. Frequent draining off and keeping the fields without water should encourage growth of weeds and their removal is one of the most expensive items of cultivation in the countries which adopt this practice. There is, however, no doubt that a good deal of water is wasted in our rice cultivation methods. It should be possible to economize, as experience and experiments have shown, that such excessive flooding as is usually practised is not essential to the growth of the crop. In some parts of Kistna it is known that crops irrigated by water lifts, yield even better than crops receiving flow irrigation. That rice can do with much less water than is usually given in the deltas is apparent from the fact that certain varieties of rice under well-irrigation where much less water is used, yield just as well as and even better than in the deltas. Flooding, however, keeps the weeds under check effectively.

The question of successfully growing a crop with much less water than what is used now, particularly in the deltas, has become specially important in these days. Due to the depression and the big fall in the price of rice, there is a desire for an attempt to change the cropping and go in for some crop more paying than rice. The main difficulty against this being successfully carried out is that under the conditions rice is grown, no other crop can grow. For instance there is a great scope for expanding the area under sugarcane but it is difficult to grow it in the deltas except in slightly high level fields. If on the other hand rice could be grown like a garden crop giving water whenever it requires, there is no difficulty in growing sugarcane by the side of it. The problem of flooding and draining will not then arise.

Rice varieties, at least a good many of them, do appear to stand such treatment but the difficulty is in controlling the weeds that crop up. There was an experiment conducted at the Samalkota station where this treatment of rice was attempted and it was found that the rice crop was smothered by weeds and the yield was very poor. At the Maruter station a number of varieties was tried under semi-wet condition, i.e., the land was puddled thoroughly as usual and after the rice was transplanted and the seedlings had established, water was drained away. There was some trouble with weeds and the field was given a flooding at the time of weeding and then drained off. No more water was given to the crop. Out of a large number of varieties tried, one of the *basangi* strains evolved at the station stood this treatment successfully and gave as good a crop, nearly 4,000 lb. of grain per acre, as if it were grown as a swamp crop. There appear to be great possibilities in undertaking research in these directions.

The total quantity of water required by a rice crop grown under the swamp conditions varies according to (1) the duration of the variety, (2) the soil in which it is grown, and (3) the nature of the particular irrigation system. Mainly to determine the size of the sluices and fix the *ayacut* for each source of irrigation, the irrigation authorities had determined roughly the duty of water. The duty of water represents the area which can be irrigated by a continuous flow of water at the rate of one cubic foot per second. We have no data at present to show the relationship between the duty and the yield of the crop, i.e., we would like to know how the yield will be affected by increasing the duty, i.e., making the available supply irrigate a larger area. Whenever there is any attempt by the irrigation authorities to increase the duty, the ryots under the *ayacut* begin to protest, and assert that their crop will suffer. Recently with the co-operation of the Irrigation Department, an attempt has been made to determine the actual quantity of water for the crops grown at the different agricultural stations apart from the theoretical one that is assumed for the tract. Such determinations have been made for rice at Coimbatore, Aduturai, Maruter and Samalkota and they are given below :—

TABLE No. 4.

Year.	Place.	Variety.	Season.	Duration in days.	Total acre inches of water required, including irrigation and rainfall.
1931–32 ..	Samalkota ..	GEB. 24.	July to December.	150	118·35
1932–33 ..	Do. ..	Punasa konamani.	July to November.	140	112·93
1933–34 ..	Do. ..	GEB. 24.	July to December.	153	102·05
1932–33 ..	Maruter ..	Garikasannavari.	December to March.	81	36·72
1933–34 ..	Do. ..		November to February.	123	53·00
1932–33 ..	Aduturai ..	Adt. 2.	June to December.	165	60·24
1932–33 ..	Do. ..	AEB. 65.	June to December.	165	59·52
1932–33 ..	Coimbatore.	Co. 3.	July to January..	160	72·23
1933–34 ..	Do. ..	Co. 3.	July to January..	160	84·79

As will be seen from the figures given, the duty is very high for the West Godavari delta because of the heavy nature of the soil and the very flat nature of the lands. There is hardly one foot of fall per mile in the level of the country and consequently the drainage facilities are rather limited. In Coimbatore there is often a difference in the level of the field by a foot or six inches within

a distance of 100 yards. The irrigation authorities are also carrying out an irrigation experiment near Gobichettipalayam under the Thadapalli channel to see the effect of either lowering or increasing the normal duty on the yield of the crop.

The total duty determined cannot give us a correct idea of the different water requirements of the crop in its different stages of growth. The greatest amount is required when water is just let in and the fields are puddled. After the crop is in flower the quantity required is less. The quantity of water required for the different stages of the crop has been determined at Coimbatore for Co. 3 and it is given below :—

	Acre inches including irrigation and rainfall.
Preparation of plots up to planting	25·63
Planting to flowering	48·27
Flowering to last irrigation	10·89
Total ..	84·79

Weeds and weeding.—Weeding is an operation, the importance of which varies with the conditions under which the crop is grown. Broadcast crop, especially that sown in soil which has not been puddled, requires much weeding and this forms one of the expensive items of the cultivation cost. Where the crop is drilled it can be minimised to a certain extent by the use of the bullock hoe. In South Kanara little notice is taken of weeds for the first crop which is usually transplanted. The monsoon rains at this time are heavy and continuous and the weeds cannot compete with the semi-aquatic plant like rice. As was mentioned already the weeding of the broadcast areas as in parts of Ganjam is done by actually ploughing through the crop after the land is flooded. It serves the purpose of both thinning and weeding. Where weeding is done by hand in the broadcast field filling gaps with the thinned seedlings is also carried on simultaneously.

In transplanted fields where hand weeding may be done once or twice according to the duration of the crop and the prevailing circumstances, the operation is not entirely for the benefit which the crop is to receive by the removal of weeds. Sometimes even when there are no weeds in the fields the trampling at the sides of the plants by the women coolies who do the weeding is considered beneficial to the crop. This trampling is said to encourage tillering and root development. The partial drying out of the fields during weeding is also beneficial to the crop. There are not many weeds which are troublesome to the swamp rice. These are usually aquatic grasses, *korai* (cyperus) and *Panicum Crusgalli*. The latter is hard to distinguish from the rice plant in the early stages, and the seed usually gets carried on as an impurity in the rice

grain. In some places the *arai* (*Marsilia diandra*) is often a troublesome weed and is usually brought into the fields with the irrigation water. At Coimbatore where some of the fields were foul with this, growing a thick green manure crop in summer was found to effectively keep it under check. In certain places there is trouble with a kind of green alga which is stated to affect the tillering of the rice plant in the early stages, if present in large quantities. Occasional drying out of the fields can easily keep this under check.

When once the rice is harvested, the whole field gets usually foul with weeds, some of which die out soon, as the soil gets too dry while others persist until the next rice season. With the letting in of water and ploughing, these weeds get buried and serve the purpose of manure.

Growth of the crop.—After the plants establish themselves they go on producing side shoots. This is an active period of vegetative development. This may pass on either directly to the reproductive development in the early varieties or enter it after an apparent quiescent or inactive interval in the late varieties. The coming on of the reproductive activity is characterized by a very rapid increase in growth and the change of the colour of foliage which becomes perceptibly dark green. The developing panicle inside the terminal leaf sheath of each shoot in a plant can be seen now, and after a week or so, the ears emerge out of the leaf sheath. A good rice crop in full flower is one of the most pleasing sights to see.

In some tracts due to too much of initial fertility in the land the plants grow too rank in the early stages with the result that the plant tends to lodge even before the ears are thrown out. This is a characteristic of some of the areas in West Godavari district and usually such rank growth is arrested either by cutting off the top leafy portion of the plant or by allowing cattle to graze the crop down to a certain extent. This 'topping' or cutting away of the terminal leafy portion of the plant has to be done judiciously if the yields are not to be affected.

About three weeks after all the earheads are out, the 'setting' of the seed in the ear commences which can be made out by feeling the flowers in the terminal portions of the ear, which on pressure exude a milky white semi-solid substance. The grain is said to be in the milk stage then. Too much of rain or any cyclonic winds at this stage of the crop might do considerable damage to it by lodging which will affect the grain formation. This should account for a large percentage of half-filled grains at harvest. If the lodging of the crop occurs still later there may not be any material harm except probably a slight discoloration of the grain and a certain amount of damage to the straw which becomes mouldy at the bottom of the lay.

It may be said generally that most of the Madras varieties are weak in the straw and invariably they are found to lodge at the time of harvest. There are, however, a few exceptions like GEB. 24 of Coimbatore, *kusuma* (Mtu. 8) of Kistna which have a fairly stiff straw and do not lodge to the same extent as other varieties. Lodging is an indication of the luxuriance of the crop, the heavier the crop, the greater the lodging. Any yield of over 3,000 lb. of grain per acre must result in lodging of the crop. Due to adverse season or lateness in planting even a crop that usually lodges can remain erect after it is fully ripe and the yield of such a crop must be naturally less—not more than 1,000 lb. per acre.

Draining the water before harvest.—The draining off of the water from the fields before the harvests is an important agricultural practice, connected with rice growing. It should be done at the right time, neither too early nor too late. As was explained earlier the harvests of the first crop in the double crop areas either synchronize with the break of the north-east monsoon or come when the monsoon is in progress. It is not usually possible under these conditions to completely drain the fields. In some bad years the harvests may have to be done when there is still water in the fields and this adds to the difficulty of harvesting and transporting the sheaves. Beside the difficulty experienced in harvesting operations, the excess of moisture in the fields encourages secondary tillering and leaf production. Due to this a certain amount of small tillers may be produced. These late tillers produce ears also which do not normally reach maturity. They have a separate ripening period of their own and it may not be possible to allow them to run their full course. Their contribution to the harvest is only chaff and half-filled grains. All these affect the quality of the produce which has to contain grains of different stages of maturity. Any amount of drying done later cannot improve the quality. The bulk of the crop in the single-crop lands and the second crop get ready for harvest towards the end of the north-east monsoon, or even later when usually dry weather prevails and there is no difficulty about draining off the water in time.

The high quality of the rices coming into the European markets from Spain, Italy and America is to a large extent controlled by judicious adjustment of the irrigation and harvest practices. It is stated that the best time to dry out the fields before harvest is when the grains are just hardening in the ear. It is said that by so doing the ripening is made much more uniform and the grain when milled has a uniform and shining texture. When the water has to be drained off, will also depend on the nature of the soil in the tract concerned. In the deltaic soils which are heavy clays and therefore more retentive of moisture, the water may be drained off much earlier than in a loose well-drained soil. It may be quite enough if the water is drained off a week or ten days before the crop is ready for harvest in such open and loose soils.

(ix) *Harvesting and threshing.*—The harvesting in South India is invariably done with hand-sickles. There is considerable variation in harvest practices in the different rice tracts. In some places the crop is cut when the grain is still partially green at the base of the panicles, whereas in other places the crop is not cut until it is dead ripe and the grain commences to shed. The time at which the crop is cut has a great influence on the nature of the produce, particularly its milling quality. Apart from the general inherent quality of grain it is recognized that any delay in the harvest gives rise to a high percentage of breakage in milling. It is a well known fact that the bulk of the Tanjore rice that is coming into the markets is unfit for conversion into raw rice while the bulk of the Ganjam, Guntur and Nellore produce is milled as raw rice and marketed as such. The difference in the milling qualities of the produce, of the two tracts should mainly be accounted for by the differences in harvest practices. Apart from the slight change in the size of the grain between the same variety, *nellore samba* grown in Nellore and that grown in Tanjore, the quality of the Tanjore product is definitely inferior to the Nellore product.

Differences in harvest practices.—In the Circars the rice crop is harvested at a stage when the earheads are just ripe and the straw is still green. The sheaves are allowed to dry in the field three or four days, and then put into stacks where the grain undergoes probably some sort of curing. The stacks are allowed to remain for a period, up to about four months, depending upon the convenience of the cultivator before threshing is carried out. In the Tanjore district, the harvest is delayed considerably and the operations of harvesting and threshing are invariably finished on the same day. In this connexion it is interesting to observe that Tanjore district imports the same white *sirumani* rice that it itself grows on a large scale, into some of the towns in the district, from the adjoining South Arcot district. This is due to the fact that in the particular locality from which this rice is obtained the cultivators adopt the Circar's practice of harvesting detailed above. That this practice does not obtain in Tanjore may be due to various reasons. There is first of all the insecurity of leaving the stacks in the field, trespass of men and cattle being much more common here than in the Circars. Secondly most of the lands are cultivated under the *varam* system, i.e., the cultivator and the landlord share the produce in definite proportions. The share of the cultivator being, however, much smaller than what obtains in other places, the landlord cannot be sure of realizing his legitimate portion of the produce unless he is actually present during harvesting and threshing operations. In the Circars, however, the lease system is more prevalent and the tenant has the full liberty to handle the crop as he likes and deliver the stipulated rental in kind within a reasonable time.

Submersion of the crop, lodging during the ripening stages and the presence of grains of different sizes contribute to a high percentage of breakage in milling. There is also considerable variation in the length of the stubbles left at the time of harvest. If as was stated previously the land could not be drained properly before the harvests, a fairly long stubble will have to be left. As a general rule in fields which can be dried completely the straw is cut as close to the ground as possible. This is also the practice where there is scarcity of fodder. In the deltas ordinarily a longer stubble is left for the first crop in the double-crop lands and this when ploughed under, serves the purpose of manure. In some places as in parts of Malabar only the earheads are cut and the straw left over is either cut again or allowed to be grazed down.

However carefully the harvest may be done, a certain amount of loss by the shedding of the grain in the field cannot be avoided. If this shedding is high and if the field is dry, special coolies are put on who try and collect as much of this grain as possible and after giving a portion of it to the owner take the balance. Whatever is still left over may be partly eaten by birds and rats. If the fields get wet before the next rice season begins, these stray grains germinate and get buried when the puddling of the fields starts again.

Threshing.—The sheaves after they are cut, are removed to the threshing floor, tied into big loads and carried by men on heads. If, as is usual in some places, the field itself is prepared into a temporary threshing floor, the distance through which the sheaves have to be carried will not be much. If the grain is over-ripe and the lead great, there will be some loss by the grains dropping during transit. Threshing in most places is done immediately or within two or three days of cutting the crop. As was mentioned earlier, in the Circars, the grain is stacked in the straw and not threshed until some months later. Here the crop can be cut a little green as the ripening continues in the straw. It has got to be dried in the fields for two or three days to prevent heating in the stack.

In the southern districts the threshing is done in two stages, the bulk of the grain is threshed by beating the sheaves on the ground, and what is left after that is subsequently trodden out by cattle. In Malabar and South Kanara where the bulk of the crop is on the green side when harvested, the sheaves are beaten out on a board or on an ordinary bench with reepers instead of planks. The straw is again subsequently threshed either by beating with sticks or by treading out by foot, men being employed for the purpose. In the Circars where the sheaves are stacked they are simply spread out and threshed by the treading of cattle.

Allowing the sheaves to dry for a few days in the fields after they are cut makes threshing easier as the grains drop off completely by beating. While the cutting of the crop a little early is expected to contribute to the better quality of the grain, it makes the threshing a little more difficult.

The ease with which the grain comes off the ears at the time of threshing, is distinctly a varietal character. There are varieties which shed their grain badly even with a little disturbance while others require hard beating to remove the grains from the ears. The extreme limit of this character—shattering, is to be seen in the wild rices which grow in swamps. Here the grains do not ripen in the earheads at all. They are shattered even before they are fully ripe. This shattering character of the cultivated rices must have come from the wild rices and we find various degrees of shattering represented in the cultivated forms. The shattering character is inherited and its inheritance has been studied at Coimbatore, in the progenies of crosses between parents which show a marked variation in the amount of shattering.

Varieties that possess this shattering character to any degree will have to be harvested early enough, while the crop is somewhat green. If this is not done a considerable amount of damage will be the result by the grains dropping off even in the fields at the time of cutting, and all along the route as the sheaves are bundled and transported to the threshing floor. Generally, grains with a round shape shatter their grains more easily than oval or long grains. For instance the *sirumani* of Tanjore has to be handled very carefully if excessive shattering is to be avoided in the fields. An example of a variety that does not shatter perceptibly is GEB. 24 which, if circumstances necessitate, can be left in the field for a much longer period than is permissible for any other variety. Of the other strains evolved at Coimbatore, Co. 2 is one that shatters badly if left in the field until it is over ripe.

In the deltas there is a great demand for labour at the time of harvests. As in the case of transplanting, the coolies from the dry tracts migrate to the deltas then and do the work of harvesting and threshing on contract. They get paid usually in kind but sometimes in money also.

(x) *Cleaning, drying and storing—Cleaning.*—After threshing, the produce has to be freed from all chaff, mud particles, and half-filled grains. In this Province no sort of power or hand winnowing machine has come into use to clean the produce. The winnowing is all done by throwing up the threshed produce in a stream against the direction of the wind. The chaff and half-filled grains are blown off to a distance and the heavier and sound grains fall nearer, the separation of chaff thus being mainly dependent on the strength and continuity of the wind blowing at the time.

The proportion of foreign matter present will depend on the condition of the crop at harvest and on the threshing practices. In the northern deltas where the crop often lodges at the time of harvest and the weather is wet, a fair amount of mud sticks to the ears. The same applies to the produce of the first crop in the southern areas where the harvest has to be done in wet weather.

The produce from the tank-fed and well-irrigated crop in the central districts is however, comparatively cleaner, there being no damage due to rain, and the cleaning is more carefully done on account of the smallness of the crop handled. The preparation of the threshing floor also influences the amount of mud and dust present in the produce. In the Circars and Nellore district, portions of fields are themselves temporarily converted into threshing floors. In the south, pieces of high ground common to the whole village, on road sides or canal bunds are used. The clean preparation of the produce in these improvised common floors is not a practicability. The tenants who cultivate the land pay very little attention to clean the produce thoroughly. They are even interested in mounting it with foreign matter to make up the quantity that goes to the share of the landlord.

The removal of stones and mud particles can only be done by sieving. Sieving however is never done as a general practice. The proportion of these impurities in the Godavari and Kistna delta produce is generally high and spoils the appearance of the produce. The use of rectangular hand sieves operated by two women as the grain is poured over it by a third coolie has been tried with success at the Maruter station. It costs less than six pies to sieve a bag of grain (166 lb.), while such cleaned produce fetches always a couple of annas more than unsieved material. A high proportion of the unwanted material in a sample, results in a low outturn of rice to paddy during milling.

Drying.—Before the produce is stored it has to be dried to a certain extent. The amount of moisture will depend upon when the harvest has been done. As the grains ripen in the head, the percentage of moisture in it gradually goes down and this has to be further reduced before the grain can be stored. The harvested grain is usually spread out one or two inches thick on a clean mud floor for a day or two and then stored. The amount of drying to be given will depend upon how the produce is to be used, whether as food-grain or as seed. In the Government farms, where most of the produce is sent out as seed, the produce is dried on masonry (Cuddapah or cement) floors for two or three days and then stored.

In countries like America and Japan the quantity of moisture present in the grain at the time of storing amounts to 12 to 15 per cent. of the weight of grain. In experiments conducted at the Paddy Breeding Station, Coimbatore, it has been found that there is usually about 15 per cent. moisture at the time of harvest. This goes down to 10 to 12 per cent. when the produce is stored in ordinary gunnies and the grain though not very good for seed purposes is found to keep well. But if the same grain is stored in closed metallic bins where the atmosphere cannot have a free play, the quantity of moisture does not go down with the result that the grain gets mouldy and bad. The quantity of moisture that can be

left in the grain with safety is about 10 to 12 per cent. of the weight of grain. So, whatever may be the method of storage adopted the produce will have to be dried to bring down the moisture to this level. It is possible that the moisture may be brought down still further by longer drying in the sun but unless such dried grain is stored in air-tight receptacles the produce is likely to absorb a certain amount of moisture from the air and come up to the level of 10 or 12 per cent. The amount of moisture absorbed by the dried grain depends upon the climatic conditions of the tract where the produce is stored. If the weather is humid due to rains, the quantity of moisture absorbed will be great.

Amount of drying necessary.—Experiments have been made at the Aduturai and Samalkota stations to determine the quantity of moisture so absorbed. At Aduturai the grain of Adt. 3 and Adt. 4 was first dried consecutively for four days on a masonry floor and weighed at the end of each day. The initial weight recorded as soon as the crop was harvested on the 7th October, which was 128 lb. went down to 115 lb. on the first day, to 112 lb. on the second day, and there was no further loss by subsequent drying for another two days. The loss on drying was about 12·5 per cent. This dried grain was stored in gunnies and left in the store room, and weights were recorded every fortnight for the next six months, until the middle of next April, when the grain is usually distributed as seed. From 112 lb. the weight gradually increased to 118 lb. during the middle of February. In February the seed was given a drying as usual which brought down the weight to 114 lb. and the weight increased again to 117 lb. in April. When the distribution of rainfall during this period of storage was compared with the changes in weight, it was found that there was a tendency for the weight to increase during the rainy weather and to remain constant at other periods. This experiment thus showed that the grain if dried beyond a certain degree it reabsorbs moisture during storing and gains in weight. The final weight in April was nearly that obtained by drying for one day in October, and any further drying was probably unnecessary.

The experiment at Samalkota was more or less the same with the addition that the seed was tested for germination at intervals. *Konamani*, a long duration variety, was harvested on January 20th and immediately bagged. Out of five bags of grain, each weighing 166 lb., one was kept as control without any drying while the other four were dried for one, two, three, and four days, respectively, before storing. Periodic weighments of bags were made at intervals until next August along with germination tests of samples drawn from each bag. The figures showed that the percentages of dryage on the original weight on the first, second, third and fourth day, were 6·9 per cent., 3·2 per cent., 1·2 per cent. and 0·2 per cent., respectively. In the case of bag No. 1, which was not dried at all and No. 2 which was dried for a day, there

was a gradual reduction in weight up to the end of the hot season, after which there was a slight rise by reabsorption of moisture and consequently a gain in weight. In the case of grain dried for four days, the reabsorption continued until the end of March, after which the weight followed the same course as that in the case of bag Nos. 3 and 4. An almost stable equilibrium was reached after two days' drying when the grain weighed about 150 lb. and any moisture lost by further drying was reabsorbed from the atmosphere.

The percentage of germination of the samples from the five bags showed a general increase as the number of dryings increased but the variation was only slight. From 94 per cent. for the undried seed, it went up to 99 per cent. for the sample dried for four days. In two days' dryings it was 97 per cent. This experiment showed that under the conditions obtaining in the Circars due to the prevalence of fairly clear weather after the harvest of the *sarva* crop two dryings on clear days should be quite sufficient for preserving the grain as seed.

If, however, the period of storage runs through a wet weather, the grain, by absorbing considerable amount of moisture, becomes unfit for seed purposes later, the germination being slow and poor. This is what usually happens in the second crop seed, *garikasannavari*, of the Godavari district. The produce is harvested in May and has to be kept until it is required next January-February for sowing. During the interval of 10 months the stored produce has to pass through two wet seasons—the south-west monsoon period, June-September, and the north-east monsoon period, October-January. To overcome this difficulty the ryot usually raises an intermediate second crop in the *sarva* season, June-October. This crop invariably suffers from a wet harvest. On account of this difficulty only some who can command the facilities adopt this practice. The area grown thus being limited there is a great demand for the produce for seed purposes and the price is sometimes twice as much as that of ordinary grain.

Preservation of seed.—Experiments have been conducted at Maruter with regard to the preservation of second-crop seed. The second-crop seed harvested in May was dried and stored in different receptacles, metallic bins, gunnies—single, double and treble, and straw bundles. When germination tests were conducted later, it was found that it was quite satisfactory in the produce stored in metallic bins. The produce stored in gunnies, irrespective of the number of gunnies used, began to lose its vitality after the fifth month of storing. The straw bundle was about intermediate between bins and gunnies. Comparative yield trials of old seed harvested in May and preserved in metallic bins and new seed harvested in October were made and they showed that the old seed was just as good as the new and at the same time resulted in an even harvest. If the seed preserved in gunnies was given occasional

dryings, an improvement by way of increased percentage of germination was obtained. It did not, however, approach the percentage secured in the seed preserved in metallic bins. Though the buying of the metallic bins for storing the second crop seed may be an expensive item which all ryots cannot probably afford, there is no doubt that the initial investment on them is more than recouped in the way of savings secured by not buying seed at exorbitant prices.

Though it may be an advantage to dry the produce very thoroughly when it has got to be used for seed purposes, such excessive drying produces a high percentage of broken rice when the grain is pounded or milled. This reduces the value of the grain if it has to be used as food. Rapid drying of the harvested produce in hot sun brings on what is known as sun-cracks, i.e., cross-fissures in the kernel, making it unfit for milling purposes. In some of the foreign countries where the produce is put on the market, artificial driers are used, where the temperature is not allowed to rise too high and thus the formation of fissures in the kernel is prevented.

Storing.—The storing here referred to only relates to the rice in husk. Husked rice is not stored for a long time. With regard to grain in husk what is meant for sale immediately after the harvest, may be stored loose or in gunnies but larger quantities that are meant for sale later in the season, have to be stored in special receptacles.

Receptacles for storing.—These receptacles vary in kind and size in the different tracts. In the Circars, large quantities are stored in specially built granaries called *gathis*. These are elevated structures built on pillars and provided with walls of bamboo mats on all sides, thickly plastered over and a *pukka* roof with projecting eaves. The capacity of these may vary from 300 to 1,000 bags of grain (1 bag = 160 lb.). Then there are the circular *puris* or *pattarais* with walls made of straw twists temporarily erected on either spherical masonry platforms or on an elevated piece of ground. These *puris* are very common in Tanjore also and their capacities are definitely less, the largest of them holding not more than 200 bags of grain. Then there are the shallow underground pits used for storing grain for short periods. This practice obtains both in Ganjam and Nellore. For the preparation of raw rice, rice in husk must be stored for some time after harvest, as there is probably a sort of curing process going on during such storage. In the case of the pitted grain, due to the heat developed, the curing is hastened and a sample that has remained in an underground pit for a couple of months is probably equal to one year old grain. The millers in Nellore, invariably adopt this practice before milling the freshly harvested produce. In the southern parts of the Province, the grain is not generally stored for a long time. The produce is usually disposed of before the commencement of the

next harvest. There are also other receptacles commonly used, the granary made of wooden planks as in Malabar, the straw bundles, *muras* used in South Kanara, and the common sun-dried mud bins used all over the Tamil districts. Big mills which buy the grain for milling and selling as rice, have special godowns attached to the mills where the grain is stored either loose or in gunnies.

The only receptacle used for storing husked rice, even for temporary periods is the common gunny. The grain stored in completely air-tight receptacles as *gathis* or underground pits does not give such a white and attractive looking rice as that stored in straw *puris*. If the grain is milled with a large amount of moisture, the rice cannot be kept long as it is likely to become mouldy and lose its nutritive value.

CHAPTER V

Special Problems of Rice Cultivation

Some of the special and peculiar practices adopted in isolated parts of the Province are detailed below.

(i) *The ' Udu ' cultivation in Tanjore.*—This refers to the ingenious practice of obtaining two crops of rice with one cultivation. This practice is to be found in the Northern and Eastern parts of the delta, where the water-supply is received comparatively late and where great difficulty is experienced in transplanting the second crop after the first *kuruvai* is harvested as it almost synchronises with the setting in of the north-east monsoon. Where water-supply is normal the usual two crops (*kuruvai* followed by *samba*) are taken. In ' udu ' cultivation, seed of *kuruvai*, the three-months' variety is mixed with seed of *ottadan*, a seven to eight-months' variety in the proportion of four to one and the mixture is raised in a dry seed-bed just before the receipt of the freshes in the rivers. The seed rate adopted ranges from two to four measures (5 to 10 lb.) per cent. of seed-bed and one acre of seed-bed is expected to plant about five to six acres of land.

There is nothing special in the cultivation practices, except that the ryots realizing the exhaustive nature of the cropping, usually manure the fields heavily. The land is either ploughed dry first and finished with puddling or it is puddled right through. The seedlings which are usually well-grown, having been obtained from a rich soil, are transplanted in bunches of six to eight seedlings to a bunch with six to eight inches of spacings early in August. The crop receives the first weeding about three weeks after planting and again twice after the early crop has been removed. After the harvest of the early crop in October cattle are sometimes let into the field to graze down the stubbles and enough water is maintained in the field to facilitate the rotting of the *kuruvai* stubbles and encourage, shooting of the late crop. The late crop ripens in February. The yield obtained will depend upon the season but an acre yield of 2,000 lb. from the first crop and about 1,000 lb. from the second, is considered satisfactory. When, however, the summer has been rainless causing the soil to crack deeply and when after the harvest of the first crop there are well distributed rains which help in the rapid shooting of the late crop, bigger yields may be obtained. An examination of the yield figures for a large number of years points out unmistakably the inter-dependence of the two crops. Whenever, due to a favourable season, the *kuruvai* crop yields well the *ottadan* yields less, but if due to a wet summer or late planting, *kuruvai* does poorly, the *ottadan* makes up for it by

an increased yield. The improvements that have been recommended by the department are (1) the use of the strains of *kuruvai* and *ottadan* evolved at the Aduturai station, (2) the reduction of the seed rate from 5 to 10 lb. to 3 lb. per cent. and planting less number of seedlings, not more than four to five in each hole, and (3) the use of green manure supplemented by either bone-meal or super-phosphate.

Though the practice is ingenious enough in that it tides over the necessity to plough the land twice as is usual with double-crop lands, there are certain disadvantages inherent to this system. In rice cultivation when once water is allowed to stand in the field after the planting, it should be maintained right through. But to facilitate the harvest of the early crop, water has to be drained off and the soil gets hard by the trampling of the soil at the time of this harvest and no ploughing is possible. The partial drying of the field also encourages considerable weed growth. The main advantages of the practice are (1) a second crop is guaranteed in tracts where the second crop freshly planted after the harvest of the first crop stands the risk of being damaged by the usual heavy and continuous rain; (2) because of the strong stubbles of the *ottadan* crop, the first *kuruvai* crop does not lodge badly if there should be a bad weather prevailing as it has the support of the *ottadan* crop; and (3) the payment of the double crop assessment is avoided.

Certain experiments have been conducted at the Aduturai station to determine the best combination of the *kuruvai* and *ottadan* strains out of the four available, two of *kuruvai* and two of *ottadan*. Two or three years' yield trials point out that a combination of strains Adt. 4, (*kuruvai*) and Adt. 7, (*ottadan*) is about the best.

This system of cultivation is not likely to extend much. Probably the area under this system is even now going down in this district. The *ottadan* rice though of a longer duration, is not considered to be of good quality and is mainly consumed by the labour classes.

Experiments with 'Udu' cultivation at other places.—Certain experiments have been conducted at the Samalkota and the Maruter stations to find out how far this practice of Tanjore could be adopted in Godavari district. At Samalkota both Adt. 3 and Adt. 4 were mixed with a number of late varieties, GEB. 24, *krishnakatukkullu*, *ratnachudi*, Co. 2, Adt. 5, etc., and grown as a *udu* crop. The total yields of the different combinations varied from 2,800 to 3,000 lb. of grain per acre whereas the average yield of the single crop in the farm was about 2,950 lb. Thus the yield was nearly the same both in single cropping as well as in *udu* cropping with the additional disadvantages that the *udu* cultivation involved an extra expenditure of Rs. 12 per acre in harvesting, and the *kuruvai* grain fetched eight annas less per bag of 160 lb.

than the local variety. Owing to the inevitable late planting obtaining at this station compared with the Western delta the system had less prospect of success than at Maruter as will be seen below.

The *udu* crop trials have been going on from 1926, at the Maruter station. Five of the short duration varieties, Adt. 3., Adt. 4., *sornavari*, *chitrakali*, *garikasannavari*, were each grown mixed with three long duration varieties, *atragada*, GEB. 24 and *krishnakatukkullu*. The combination of Adt. 3, with all the three gave increased yields over the pure long duration crop and so also one of the combinations of Adt. 4, with *krishnakatukkullu*. In all the rest, the total yield of the two crops was below the yield of the single crop. In a bulk trial, in one of the rich plots of the station, Adt. 3 with GEB. 24, gave 4,500 lb. of grain per acre while the average yield of the pure crop for the station was about 3,000 lb. only.

The proportion in which the seed of the two varieties should be mixed was also experimented upon. Three proportions of 1 :1; $1\frac{1}{2}$: 1; and 2 : 1, of early-crop seed to late-crop seed were used. It was found that in all the three, the total yields were uniformly the same. The figures definitely showed that the yield of the short crop increased as the proportion of this seed in the mixture was increased from 1 to 2, but the yield of the long-crop came down proportionately thus making the total almost the same.

Experiments were also conducted to compare the *udu* method against the pure crop that was either topped to prevent lodging or was non-topped. Trials were also made with early sowings and late sowings. The general conclusions reached from these *udu* trials are : (1) the scope for the adoption of the system in the delta is limited; (2) it can be adopted for soils of above average fertility where topping has to be done, and where facilities for early sowing and the planting of the crop before the end of June exist; (3) for these conditions a mixture of Adt. 3 and either GEB. 24 or *krishnakatukkullu* planted rather close in doubles would be advantageous; and (4) the system is definitely unremunerative for lands of average fertility or where the planting has to be done late.

(ii) *The second-crop problem of the Godavari delta.*—In the Godavari delta in the double-crop areas, the first crop *sarva* is grown between June to November and the second crop *dalwa* between February to May. The area allotted to the *dalwa* crop is about 28 per cent. of the first-crop area and comes to about 200.000 acres of which the Western delta alone contributes 125,000 acres.

Before the introduction of the canal system, the *dalwa* cultivation was confined to the margins of Collair lake and was extended into the delta nearly 50 years ago. By experience, the people have determined the most favourable time for planting the *dalwa*

to be after the middle of February; this period is found to synchronise with a favourable change in the weather conditions, rise of temperature and the onset of *pyru gali* or corn winds, and plantings done earlier to this period invariably succumb to pests and diseases. Later plantings resulting in bumper crops the area under the second crop has gradually increased. At the time of the Great War, the price of rice went up and this gave a further impetus to the increase in the second-crop area until a stage was reached beyond the safe limits of the average water-supply in the canals. Indiscriminate growing of the second crop led to the difficulty of uncultivated lands in the midst of the second-crop area getting affected and becoming alkaline consequent on the alternate wetting and drying. The Irrigation and Revenue authorities took some action in the matter by sitting in conference every year and deciding upon particular canals that should be opened for the second crop, preference being given to portions where the first crop either failed or was poor due to submersion or flooding in the *sarva* season. Even then the area under the second crop rose from 66,500 acres in 1900 to 223,000 acres in 1923. Government have now formulated measures to put a check to further increase in the area and to localize the second-crop area for every season.

The advantages that have resulted in the introduction of the second crop are: (1) It has contributed to increased yields in the main crop, firstly by setting up a general awakening in the matter of manuring rice and secondly by checking the rank growth and the consequent lodging in non-cropped areas. (2) The periodic cultivation of a second crop counteracts the occurrence of 'gulla,' a peculiar and harmful looseness of the soil common in lands where a single crop of rice is grown alternating with either a long period of fallow or a garden land crop. (3) It has increased the cultivable area in the coastal taluks of the district where the first crop invariably fails. (4) In the Eastern and the Central deltas, where large areas are under coconut gardens and sugarcane, the second crop has come in to augment the fodder supply. (5) It has increased the level of lease rentals of tenant cultivators who are on the increase and who mainly depend upon the second crop for grain and fodder, the produce of the first crop being utilized to meet the rental.

Stem-borer attack and the second crop.—Among the disadvantages, the most important one is the development of the chief rice pest, the stem-borer. Previous observations on the incidence of this pest had disclosed that the percentage of incidence varied between 0·2 to 0·58 in the single-crop lands and between 1·7 to 4·4 in the double-crop areas. Studies on the incidence of the pest on the station for a number of years showed that the pest attack is manifest in the rice crop from the end of October to early February, affecting the first crop while it is in ears and the second

crop while it is still in the seed-beds. Ryots have been shrewd enough to realize the situation and have adopted certain means of reducing the incidence. They have gone in for shorter duration varieties for the first crop so that flowering of the varieties will escape the critical period of insect infestation. It is found that varieties that flower up to early September, are free from the pest, later flowering varieties exhibiting increased incidence. In one of the trials a variety of rice flowering towards the end of October showed 3·13 per cent. of pest incidence but this increased to 26 per cent. when the flowering was delayed to 12th November. The failure of the early planted second crop is due almost entirely to a severe incidence of the stem-borer. Though the insect continues to lay eggs even after January, it has been found that the egg masses collected later than January are all parasitised. Thus, the ryots have been able to dodge the caterpillar problem by going in for early duration varieties for the first crop and by delaying the planting of the second crop.

Sometimes it is stated that the second crop growing depletes the soil fertility. But this appears to be more imaginary than real. There is no second crop coming in every year in the same area and even then there is a long interval between the two crops and the fairly intensive heat during the period of six to eight weeks is enough to bring the soil to a nice condition for the following first crop. The interval between the first and second crop also permits of the growing of leguminous crops either for green manuring or for fodder, a common practice with the ryot. The work at the Maruter station has also shown that it is possible to raise a good green manure crop of daincha (*Sesbania aculeata*) for the *sarva* crop by sowing it in the standing crop of *dalwa*. It has also been noted that the fertility of the land can be maintained by suitable manurial practices.

The main difficulty with the second crop, as was mentioned earlier, is the inadequate water-supply at the later stages of the crop. Alternate wetting and drying caused by the shortage of water tends to make the soil more alkaline and the inadequate water-supply in the end does not usually allow the growing of a green manure crop.

The problems with the second-crop growing amount to this. The fields planted earlier than February, succumb to insect pests and later planted fields, though they escape the insect attack, suffer from water shortage. Inadequate water-supply affects the proper setting of the seeds and the physical condition of the soil which is detrimental to the following first crop. Regular seed-bed sowings do not commence until Christmas or the first week in January and the plantings are not done before the second week in February. Crops planted in late February, require water up to the end of April, but the canals are closed for general supply, by the middle of April. With the difficulty of water

shortage in April, Government could not allow any further increase in the second-crop area. So, in 1928, they localized the second-crop area in three main zones in the Western delta which has the largest area under the second crop :—

(*a*) *Excluded zones* consisting of high level lands are permanently excluded from the second-crop area;

(*b*) *Rotation zones* that get a chance of growing a second crop once in three years; and

(*c*) *Permanent zones* that are allowed a second crop every year, the lands either being liable to submersion or where a first crop cannot be grown satisfactorily.

This system has been found to work fairly satisfactorily.

Experimental work at Samalkota.—This second-crop problem has been one of the main lines of investigation at the Samalkota station for a number of years, the experiments being along three directions. One was to try a number of short-duration varieties by planting them early in the second-crop season to see whether any of them would be suitable for such planting. The second was to grow a short-duration variety in the main-crop season and to follow it immediately with a long-duration variety to mature in February or March. The third was the comparison of the yielding capacity of a broadcast crop sown in the first and third week of October, with a planted crop in November, the time of sowing being the same in each. This last arose out of an indication that a broadcast crop was less affected by stem-borer than a transplanted one. *Udu* cultivation mentioned previously was also tried.

These trials have all gone on for a number of seasons and though valuable indications have been obtained, the results, so far as the solution of the problem is concerned, are a complete failure. None of the early varieties could be planted successfully early in the season. As regards the intermediate cropping—a long duration variety followed by a short one—it was found that the month of November was the latest at which transplantation could be done, as otherwise the advantage of cropping out of the normal season was lost. In the test with a large number of varieties for a long period, no variety was found that would withstand the adverse seasonal conditions sufficiently to make its cultivation a practical proposition. It was found that even small differences of a week or a fortnight in the time of planting considerably affected the crops.

Experimental work at Maruter.—With the available results of all these trials at Samalkota, the problem was tackled also along three lines at the Maruter station; (1) to evolve a strain in the important local second-crop variety, *garikasannavari* which could be harvested earlier without detriment to yield, (2) trial of other short-duration varieties from outside in place of *garikasannavari*, and (3)

modification of the different cultural practices with a view to advance the harvests.

As regards (1), one strain has been evolved (Mtu. 9) which in addition to giving a higher yield than the local could be harvested a week to ten days earlier. This has satisfactorily finished the trials at the station and in the districts and its distribution is in progress.

Regarding (2), there are a number of varieties of even shorter duration than *garikasannavari* but they give a satisfactory yield only when planted late so that there is no saving in time.

As regards the last item, several trials have been going on with periodical plantings, alteration in the time and rate of sowing seed-beds, different methods of raising seed-beds, different ages of seedling and different spacings given at planting and observing their effect on the time of flowering of the crop. Planting seedlings raised in a thin-sown nursery was found to advance flowering by three to four days. With seedlings raised under wet conditions, it was found that the greater the age of the seedling at planting time, the quicker it flowered but the final yield was definitely poor. If the seedlings were raised under semi-wet conditions, the crop was found to be good in stand and yield but there was no advance in age. After repeated trials and extensive observations made on the stand of the crop obtained by planting volunteer seedlings that had got self-sown in the fields in November, it was found that seedlings raised under wet conditions to begin with in November and then allowed to dry up, and planted in early January when the seedlings were nearly 70 days old, gave a satisfactory crop, and at the same time came to flower nearly a month in advance of the regular sown crop. The seedlings raised under such trying conditions were found to be free from the infestation of stem-borer and established much more quickly than ordinary seedlings raised under wet conditions. The experiment has been extended to large scale trials for two seasons and the results appear to be satisfactory.

From the results obtained, the following suggestions emerge out as worthy of practice :—

(1) For permanent *dalwa* areas where the first crop is either not cultivated at all or damaged by submersion, nurseries can be sown in November and the planting done in the first or second week in January. The irrigation for this crop might be cut off by the end of March.

(2) For areas where a first crop is grown but kept under continuous puddle, nurseries may be sown towards the end of November or early in December, and planting done in the third week of January. The irrigation for this might be cut off by the first week of April.

(3) For areas that grow a catch crop of sunnhemp, planting may be done during the first or second week in February, nursery being sown in early December. Irrigation for this might be cut off by the second week of April.

In the course of these experiments it was found that the first crop varieties like *basangi*, *akkullu*, *krishnakatukkullu*, can be used for the second crop, using the previous year's seed. The sowing of seed-beds can be made in November and seedlings transplanted in January or early February, come to harvest along with *garikasannavari*.

(iii) *Double transplantation.*—In a few places there is the practice of transplanting twice. Seed is first thickly sown in the nursery and then planted close together in bunches. Subsequently, these are split up and planted again in smaller bunches. The only advantage with this practice is that it is possible to use much older seedlings than would otherwise be the case. Planted close in bunches, the plants cannot tiller and if there is either scarcity of water or too much of it at the planting season it is possible to tide over this period by double transplantation. The conditions obtaining in the Central delta of Godavari are such that facilities exist for early sowings but not for early plantings. To prevent the early-sown seedlings from getting too rank they are planted in a second nursery after a month, about three inches apart, and the same replanted a month later in the main fields with wider spacings.

Experiments with double transplantation.—To determine the merits of this practice an experiment was laid out at the Samalkota station and continued for three years consecutively. Two plots in the same field were transplanted on the same date, and two months later when the seedlings had become thoroughly established, the crop in one plot was pulled out and re-transplanted. The results showed that there was nothing to be gained by the second transplantation which was an added expense to the cost of cultivation. Though the experiment was later discontinued as uneconomical, it was noticed that the double transplanted crop had produced more grain and less straw and was thus comparable to the planting of old seedlings and seedlings from the thin sown seed-beds in other experiments. Probably, the greater ratio of grain to straw is related to greater root development. This might account for the double transplanted crop suffering less from lodging in fields which are inherently over-fertile. The practice though it involves additional expenditure has compensating features about it like saving of seed, and timely planting of healthy and strong seedlings which will grow and be less liable to lodge.

In a later experiment conducted at this station three pounds of seed were sown in one cent of nursery and the seedlings were enough to plant three cents in the first instance and 34 cents finally; while

in single transplantation the same quantity sown in one cent of nursery was enough to plant twelve cents only. The final yields were in favour of double transplanting by about 9 per cent.; but as the once-planted plot had been sown 25 days later than the double-transplanted plot, it cannot be said that the increase was not due to the earlier sowing of the seed-bed in the case of double-transplanted crop. The difference in the total age of the crop could easily account for the 9 per cent. difference in the yield.

At the Maruter station in connection with the studies on the problem of lodging, a characteristic of rich soils, double transplanting was found to be one of the agricultural practices that could be made use of to prevent lodging. The final yield of the double-transplanted crop was, however, 10 per cent. less than the crop where the shoots had not been cut in the early stages to prevent lodging. A regular experiment was later carried out with seven varieties of varying durations, to assess the comparative merits of single and double planting. Early and late sowings and thick and thin sowings had also been included in the experiment. In the final weighments two varieties had to be discarded as they grew too rank and lodged prematurely. Among others, the yield differences were definite only in the variety *akkullu*. The general results of the experiment were that the yield difference in favour of double planting was very little. It was the thin sowing of the seed-bed that had the most prominent effect on yield.

This practice of double transplantation prevails in certain tracts of other provinces as well. For instance, in Thana district of Bombay, in the stiff black soils, this double transplanting is practised to reduce production of straw and increase production of grain. The conditions obtaining here are the same as in West Godavari where the practices of double transplanting and topping the crop in the early stages are resorted to. In parts of Assam also this practice obtains. In an experiment conducted at the Jorhat farm in Assam, double transplanting was found to be distinctly beneficial. This experiment, however, amounted only to the comparison of one month old ordinary seedlings with two months old well-tillered and strong seedlings obtained by a first transplanting. The difference in yield must be mainly due to the better vigour of the seedlings available for double transplantation.

In Malaya, it is mentioned that in lands of high fertility, there is a practice of transplanting the seedlings into the field in clumps which are split up successively two or three times before the final planting. This practice is stated to stimulate general growth and particularly tillering to such a degree that a much smaller quantity of seed would be sufficient to plant an acre. This method is, however, not considered useful for lands of low fertility.

Mention is made of an experiment in British Guiana where double transplanting (first planting after four weeks and the

second transplanting three or four weeks again later) has given a big increase in yield, the increase more than compensating for the increase in expenditure involved. The double transplanting resulted in stronger seedlings, more efficient weed control and considerable saving in seed.

It may be concluded that this practice might be of some benefit for special tracts (1) where either facilities for early planting are not available or early planting is not practicable, and (2) where early planting results in too rank a vegetative growth due to over fertility of the soil. The advantage of the practice is mainly due to the strong and vigorous seedlings available for transplanting and it is probable that the same advantage might even be gained by growing the seed-beds thin, and planting the well-grown vigorous seedlings, without having to incur additional expense in transplanting twice.

(iv) *Two crops in the ' sarva ' season of Godavari delta.*—In a large area of the Godavari Western delta, scattered areas exist, which are favourably situated for planting the crop early in the season. Due to such early planting and to the high fertility of the soils, the crops grow very rank and such rank growth has to be cut back to prevent loss of yield due to premature lodging. This cutting back has to be done judiciously if loss is to be prevented. To make better use of the situation an *udu* cropping was tried and this gave nearly a 30 per cent. better yield than the single crop. As an alternative to this system, the growing of two crops, an early and a late, independently one following the other was considered worthy of trial. The possibilities of doing this have been under investigation at the Maruter station for a number of years.

While the choice of an early variety to be planted first is easy enough, the main difficulty lies in the choice of the long duration variety to follow the early one. It should be such as would come to flower almost at the same time as the other main crop varieties of the delta, as otherwise it will be subject to the attack of stem-borer. For the first two years, preliminary observations were made to choose the right varieties for this trial. Among the early varieties, *wateribune*, *kasipichodi*, Adt. 3 and *swarnalu*, and among the late varieties, GEB. 24, *krishnakatukkullu*, *atragada* and *garikasannavari* were considered. Of the early varieties Adt. 3 was decided upon as the best for this trial. With regard to the late varieties observations taken on the severity of the stem-borer attack showed that GEB. 24 was tolerably resistant while *krishnakatukkullu* and *atragada* showed nearly 50 per cent. infestation Thus the two crops chosen for this trial were Adt. 3 followed by GEB. 24. This cropping was compared to the single crop GEB. 24 in adjacent plots for three seasons. The total yield of the two

crops together was distinctly better than the yields from the single crop by 53 per cent. in the first year, 22 per cent. in the second year and 82 per cent. in the third year. Later trials with this method have shown that variety *moshiopolo* of the Ganjam district and Co. 3 of Coimbatore are even better than GEB. 24 for this kind of cropping. The results were definite enough to point out the feasibility of adopting this practice. It should be particularly useful to cultivators of small holdings as they can easily increase their produce from the land by nearly 50 per cent. with a little extra trouble. Of course, adequate regard will have to be paid to maintain the fertility of the fields by suitable manuring.

This experiment has also given some indications about the details to be adopted to make the scheme a success. One important limiting factor for the trial was found to be that the seed-bed for the second crop has to be raised dry and early in the season. Seedlings from a late seed-bed raised under wet conditions when planted in September after the harvest of the early crop, are found to be easily susceptible to the attack of insect pests. The early and dry sowing gives the seedlings an early start but at the same time makes them remain dormant in the nursery until required for planting. Moreover, the dry seedlings also establish sooner when planted out and are found to possess sufficient hardiness to resist the unfavourable conditions attended with late planting.

(v) *Cultivation of rice in salt lands—' Kaipad ' cultivation in Malabar.*—In parts of the West Coast there are areas near the mouths of streams subject to tidal waves and annual inundation within a few miles of the sea coast. The soil in these areas is a stiff clay, dark in colour. It is extremely impervious, rich in organic matter, due to deposits accumulated through years. The fossils of plants and shell fish suggest that these were originally under the sea and there are also indications of the existence of salt pans in many places. Such places are usually overgrown with mangroves which have to be cleared before the land can be made use of to grow a crop. The rice cultivation in these lands is known as ' *kaipad* ' cultivation meaning literally sour land cultivation.

After the jungle is cleared, the area is protected from the tides by big bunds often strengthened by a row of mangrove plants or even with rubble. A few drainage channels are cut and these communicate with the river through narrow wooden sluices across the bunds. The lay-out is a slow and costly process and the soil for the bunds has often to be brought down from long distances, and thus it may take many years before the bunds are built strong enough to withstand the currents.

The cultivation starts in January-February when the area is drained thoroughly through the sluices and the land is laid out into rows of loosely heaped mounds by *mammatties*. These mounds conical in shape vary in size according to the level of the field in relation to the tide level of the river. They may vary from 1½ to 4 feet in height and 2 to 4 feet in diameter. These mounds are so made with sufficient space between the clods of soil for water and air to pass through that, when dry, during the next season, these blocks may be dismantled block by block and rebuilt again.

The first heavy showers in June wash down most of the salt from the mounds. This water is drained off and fresh water is let in just up to the top level of the mounds. The top of the mound is slightly stirred and well-sprouted rice seeds are sprinkled over the mounds on a showery day and more water is let in to submerge the mounds to a depth of three to four inches. Four days after sowing, the water level is lowered and when the seedlings are about ten days old fresh water is let in to stand to about half the height of the seedlings. The frequent change of water helps in washing out the salts and stimulating the rice plants to grow. Even short spells of sun and floods may do much harm to the crop. About 100 to 150 lb. of seed are sown per acre.

After about thirty to forty days, the water is drained off on a cloudy day, and the weeds are pulled out and buried. The mounds are cut up into small bits with a few seedlings in each, and they are distributed in the fields around the mounds. The work has to be got through hurriedly and when finished, the field is brought to its original level with seedlings distributed over it about six inches apart. Water is now allowed to stand to about half the height of the seedlings which soon establish and tiller profusely.

The after cultivation consists only in the careful regulation of the water and maintaining the bunds safe. Water from the river is not usually let in unless other sources are blocked. The crop flowers in September and after this about two to three feet of water have to be maintained to prevent the crop from lodging. Water is drained off only after the earheads ripen and the crop is ready for harvest by about the middle of October. Any hot spell before the crop ripens is harmful to the crop. At harvest the earheads alone are cut, and the field is filled in with fresh water to submerge the stubbles and this water is kept on until January. The yield of the crop may vary from 1,500 to 3,000 lb. per acre.

No manuring is ever done to the lands as the decayed vegetable (stubbles and weeds) and animal matter present replenish the soil. Though in normal years, the actual cultivation of the crop does not entail any special expense, it is the maintenance and repairs to the bunds and sluices that form a heavy item of expenditure.

There is usually some subsidiary income from these lands. The bigger bunds planted with a row or two of coconut trees bring in some produce. Sometimes the outer bunds may also be planted with *ragi*. In some places when river water is let in after the harvest of rice, varieties of fish and prawns breed inside the enclosure and these may be collected and sold at the time of draining in next January. The majority of the depressed classes are attached to this class of land which provides them with employment not only in rice cultivation, but also in some cottage industries like coir manufacture, mat making, fishing, etc.

The chief varieties of rice grown in these salt lands are *bali* (an awned variety), *orkayama* (a *kayama* suitable to saline lands) and *orkuttadan*. Of the above, *bali* is the most important and is the variety grown in *kaipad* lands, with bunded enclosures described above. On the outskirts of *kaipad* land, there are no bund enclosures and here *orkayama* is grown which is said to stand salinity even better than *bali*. In this class of land the mounds are formed only in June after the rains start and seedlings brought from outside are first planted on these mounds instead of sowing seeds. After a month these mounds are dismantled as in the case of *bali*. Because of the less protected nature of the land, the crop is usually rather poor. These areas can, however, be gradually converted into *kaipad* lands by later bunding.

Even among saline areas there are certain low lying places where water stands to a greater depth and for a longer period making transplanting impossible before September. Though these places are also bunded and provided with sluices the method of cultivation adopted is different. The variety of rice grown here is *orkuttadan* which is a deep water rice. With the first rains the land is ploughed once or twice and the later rains convert this area into small lakes and a large amount of silt is deposited on the ploughed surface by the floods. This water can be drained off only when the south-west monsoon abates and the land is puddled and transplanted with seedlings grown in the adjacent coconut gardens. The excess of water is drained off now and then and a weeding is also given. The crop can be harvested in January-February and may yield about 1,500 to 2,000 lb. of grain per acre. Unlike *bali* or *orkayama* the straw of this variety is cut and made use of for thatching purposes.

There are certain high level lands adjoining *kaipad* lands which also develop a certain amount of salinity and have to be attended to if they are to be made use of to grow crops. The methods adopted to keep down the salinity in these lands are: (1) digging the land after the harvest of rice and leaving it in clods or in ridges and furrows until the season comes again for transplanting, (2) trenching at intervals and replacing soils in the saline patches by good soil brought from outside and (3) providing high and strong bunds to prevent saline water getting in at times of high tide.

Saline lands in Tanjore district.—Such saline lands exist in parts of Tanjore district also along the coast. The annual rainfall here is somewhere between 45 and 60 inches, almost all of it being received during the north-east monsoon.

The nursery is prepared in July, usually in a high level field. It is first flooded with sweet water and subsequently drained to remove the salt if any. It is then heavily manured with cattle manure and village rubbish and the seed-beds are prepared in the ordinary way, under wet conditions using sprouted seed. The seed-rate adopted is about 60 lb. sown in ten cents of land to plant an acre. The transplant field is ploughed once or twice meanwhile and the seedlings are transplanted when they are about 50 days old. The seedlings are planted in bunches about a foot apart with four to six seedlings in a bunch. It is considered safer to plant more seedlings in the bunch as the salinity of the land is likely to kill some of them. While the better class of land receives practically no manure, the poorer is sometimes manured by penning sheep or cattle. The crop comes into ear by the middle of November and is harvested by the middle of January. The main principle observed is that the planting time should be so adjusted as to make the flowering of the crop synchronise with the heavy north-east monsoon rains. When salt-water gets into the field during high tide and gets out during the ebb tide, fresh water is let into the fields and drained off to remedy the bad effects of the salt-water. The success of this crop depends upon the manipulation of irrigation and drainage with rain-water and water from rivers. The after cultivation of the crop does not materially differ from what is usually adopted for rice and in good seasons the crop may yield anywhere from 1,200 to 1,500 lb. of grain per acre.

The chief variety of rice grown in these areas is what is known as *vadan samba* and this is said to stand a fair amount of salinity in the soil.

Coastal tracts of Godavari and Kistna.—In parts of Godavari district, mainly in the Central and the Western deltas there are large areas which require special treatment for growing rice on them. In the Western delta the areas consist of the coastal regions at the tail-end of the main canals, which are subject to submersion by tidal waters and excessive drainage from higher portions of the delta. The soil here is generally alkaline, and along the coast it is sandy. The first crop, June to November, fails completely in certain seasons but water for a second crop is usually given every year which is used either to grow a crop or to wash off the accumulated salts.

There are such lands in the Central delta also along the backwaters known as *parra* lands. To bring them under cultivation, it is just necessary to surround them by high embankments fitted with one way tidal gates for drainage. The first few years of reclamation provide no return, and consist in an alternate drying,

flooding, and draining to get rid of the accumulated salts. The necessary state of sweetness required by a rice crop is indicated by the growth of bulb grass (*cyperus*) and before this appears it is waste of time to attempt to grow any crop. Silt and river sand are carted on, whenever possible, to improve the texture after the washing out of the salts. When the land has become fit to grow a rice crop, the canal water is let in, to wash away the salts accumulated in summer and seed from a crop of other *parra* lands is sown. Seed from an ordinary wet land does not thrive, unless it has been grown first in *parra* lands. Only surface cultivation is practised for some years and the cultivation is made deeper and deeper as the soil improves. The crop depends to a large extent upon the amount of rain received and the yield is low and precarious, and in some years no produce is obtained at all. Persistent efforts and the gradual improvement of the soil by addition of silt and bulky organic manures as municipal rubbish can alone solve the difficulties. These lands are cultivated by people owning normal wet lands elsewhere.

(vi) '*Cole*' *cultivation of South Malabar.*—There is another special method of rice cultivation known as *cole* cultivation obtaining in parts of South Malabar in Ponnani taluk. The *cole* areas are stretches of land usually under water almost throughout the year situated close to canals and back-waters. The access to sea is usually protected by a masonry dam provided with sluices to empty the water from the areas into the sea. The whole area is divided into blocks of 50 to 100 acres with strong impervious high double bunds with a four to six feet space between, which is used as a channel where water is stored. These channels are connected to the outlet into the sea on one side. The bunds and the channels themselves are the means of traversing the area. The cultivation of these areas begins after the close of the north-east monsoon. A number of cultivators owning lands in these areas join together and arrange to pump the water from the land into the channels where it is stored. This pumping was used to be done by *chakrams* or water wheels previously, but now one finds a number of oil engines installed by private individuals who charge for the baling out of the water at so much per acre. After the water is baled out into the channels the land is ploughed lightly and the crop is sown. In some places the soil is too soft to admit ploughing by cattle. In such cases levelling is the only operation attended to before putting in the crop.

The crop usually grown is *cheera*, a three to four months' variety. It is either broadcast or transplanted from seed-beds raised outside. Since the crop is grown in a period when there are usually no rains, the crop requires plenty of irrigation. This is managed by baling in the water from the impounded channels back to the fields. If there are any rains and if there is already too much of water available in the channels, the excess water

is drained into the sea. The success of the cultivation depends upon storing the right quantity of water in the bunded channels. In some years it may so happen that the available supply will not be sufficient to ripen the crop in which case, the crop must necessarily fail or the outturn will be poor.

Under normal conditions the crop gives a satisfactory yield of 1,500 to 2,000 lb. of grain per acre. The cost of cultivation will usually be Rs. 35 to Rs. 40 per acre, of which Rs. 8 to Rs. 10 has to be paid for the engine-owner to pump out and pump in water.

(vii) *Deep-water rices.*—Mention was made already of the scattered small areas of single-crop lands in parts of Malabar known as *karinkora* lands. These areas occur generally where the catchment area of the surrounding hills is out of all proportion to the basin below. During the heavy south-west monsoon these areas remain flooded with three to five feet of water and since it is not possible to drain them, nothing is done here until the monsoon abates in its strength. After September they are usually planted with a long duration variety (seedlings being raised elsewhere), and harvested in February.

Rice cultivation in Collair tract.—Though the real deep-water conditions obtaining in parts of Bengal, Orissa and Assam, do not exist in Madras, there are portions in the Collair tract in the Kistna district where deep-water conditions prevail to a small extent. This tract is situated between the two great irrigation systems of Godavari and Kistna and a large amount of natural drainage finds its way into this. In addition, the drainage of the upland tracts comes as sudden floods through a number of wild streams that empty into this lake. The Collair lake itself must have once been connected with the sea and by the receding of the sea it is left as a hollow stretch of land nearly 150 square miles in extent. While the sources of in-flow into this lake are many and varied, there is only one outlet from the lake into the sea, and even this outlet ceases to function effectively during heavy rains. There are a number of islands in the lake where the fishing-folk live in hamlets. Though the lake gets full by August-September the water begins to subside from December onwards and by March a greater portion of the lake dries up affording grazing to the large herds of cattle belonging to the cultivators in the taluks bordering the lake.

Cultivation in the area covered by the water-spread of the lake is of a very speculative nature and until the harvests are actually finished one cannot be sure of the fruits of his labour. In the main crop season, the damage is likely to occur firstly by the submersion of the crop and secondly by the swarm of birds which usually visit the crop at the ripening stage. In the second crop, damage may arise from either scarcity of water or heavy thunderstorms sometimes occurring in early May.

Adjoining the regularly cultivated *patta* lands in the villages on the margins as well as in the islands of the lake, there are still vast areas of unsurveyed lands. There is now a system adopted from 1916 by which the Government allots these unsurveyed lands to individuals every year at the rate of not more than an acre to an individual. Since the proper cultivation of the area entails considerable amount of labour such as putting up of bunds, cutting down of weeds and burning them in summer, the insecurity of the tenure does not allow the cultivators to attend to them satisfactorily.

The whole area can be divided into: (1) Areas on the margin of the lake—all surveyed lands having irrigation facilities from the Kistna and Godavari canals, where a first crop alone is cultivated. (2) Islands in the lake—these depend solely on the Collair water which has to be lifted by mechanical means. Oil engines have come into use recently. (3) Unsurveyed area, cultivable only during the second-crop season as the Collair water recedes. The cultivation of the first two classes is just like what is practised in the deltas except that seed-beds can be raised only after the canals are opened. Sometimes seedlings are also bought in the delta villages at high prices.

The chief varieties grown on the margins of the lake and in the *lankas* are *konamani* and *akkullu*. If the water in the lake rises too soon after planting, the seedlings will be damaged but if the rise comes on after the seedlings have well established themselves, there is practically no harm done even if the water rises to a level of three or four feet. It is found that the variety *konamani* stands submersion during the shot-blade and earing stages even better than the deep-water rices of Bengal introduced here some years ago. These foreign deep-water rices are practically going out of cultivation.

The second-crop area cultivated between February and May is restricted to the Collair bed and most of the unsurveyed lands. As the water recedes the land gradually gets ready for cultivation, from December onwards. The seed-beds are prepared on the borders of surveyed fields by bunding them and baling out the excess water. Weeds are removed, the land is puddled and sprouted seeds are sown. Irrigation is given if necessary in the beginning. After some time no irrigation is given and the plots are allowed to dry and crack. The leaves of seedlings all get dried up at the time of pulling and the pulling is done dry when 45 to 60 days old. Before planting, the seedlings are kept heaped in the wet mud for three nights when fresh roots appear. These are then planted and are said to be not only free from insect attack, but also do not break after planting, when birds visit the fields in large numbers and trample the plants. After March there is scarcity of water in portions and water will have to be lifted by *kariem*, an indigenous

water-lift. The plots are usually very weedy and the water scarcity encourages weed growth. With all these troubles the cultivation is naturally precarious.

The chief second-crop variety of the tract is *nallaralu* a variety with black glumes and awns. *Garikasannavari* and *potti kesari* are also grown. *Nallaralu* is said to resist drought and it does not also shed the grain during the gales experienced late in April or early May.

(viii) *Ratooning in rice.*—There is a practice, in a very small area round about Chingleput, of ratooning rice. In some of the clayey soils irrigated by tanks, after the harvest of the crop in December–January, the field is weeded and irrigated again when the stubbles shoot up and give a small crop. In some exceptional years the ratoon crop is expected to give as much yield as the main crop itself. The special variety which is treated this way is known as '*uthiri kar*'.

Observations have been made on the ratooning of rice at the Paddy Breeding Station, Coimbatore. Ratooning is due to the development of the axillary buds at the nodes of the stubbles left after the harvest. Though the actual stooling of the stubbles is greatly controlled by the time of cutting the first crop and other environmental conditions, the development of the buds and their growing into new shoots appears to be essentially a varietal character. If a variety with an inherent capacity to ratoon, is cut just at the time of ripening, when the straw is still somewhat green and the soil still moist or, supplemented by further supply of water either by irrigation or rain, the stubbles shoot and give a secondary crop. If, however, the crop is harvested when it is dead ripe and there is no supply of water to the soil, the stubbles do not shoot.

Records were taken to compare the duration, height of plant, length of panicle, setting of grain, size of grain, and seed vitality in the main and ratoon crops. It was found that all the characters were less pronounced in the ratoon than in the main, except seed vitality. The reduction in the size of grain is sometimes made use of by ryots to meet a particular difficulty. Rices do change their grain size according to the locality in which it is grown. Any fine rice by repeated growing in the heavy delta soils tends to become coarse and occasionally by the use of the grain from the ratoon crop for seed purposes, this coarseness is minimised temporarily.

Though the grains from a ratoon crop are smaller in size, their productive power does not in any way get affected. Experiments have been conducted at the Aduturai station to use the ratoon crop for seed purposes in a number of varieties and there was no defect either in the vitality or productive power of the seed.

Ratooning is not by any means to be advocated as an economic proposition. To hoe the soil, and to keep it wet in a tract experiencing water scarcity even for a normal crop, the outturn from the ratoon crop will hardly meet the cost of the operations, but if by any chance, the weather is favourable and if the rice variety grown is capable of ratooning satisfactorily, there is no doubt that it will be worth while making use of the practice in certain special tracts where no other economic summer crop could be successfully raised.

CHAPTER VI

ROTATIONS

In the wet-land rice, on a large proportion of the area available for cultivation, there is practically no rotation practised. Rice follows rice, year after year. In some places although rice may be grown year after year, with sometimes even two crops a year, there is a practice of taking a catch crop of some pulse, black-gram, green-gram, cow-gram or horse-gram. Usually this is sown in the standing rice crop a fortnight before the harvest when water is drained off. Sometimes, sunnhemp may be grown after rice, for fodder purposes as in Kistna. In a few places where facilities exist, instead of sowing these catch crops in standing rice, the land is ploughed after the harvest and then the pulse is grown. Gingelly is sometimes grown on wet lands either after the harvest of rice or later, if a favourable rain is received to plough the land and sow the crop. Besides the catch crop rotation, the most important of other crops which are grown in actual rotation with wet-land rice, are sugarcane, betel vine, plantain and turmeric. In South Kanara, tobacco sometimes follows the main rice crop in the coastal tracts. It must be understood, however, that all these crops are confined to places where the soil is not too heavy and where facilities for irrigation and drainage exist. With the above general remarks the rotations adopted in each individual rice tract may be mentioned. The kind and nature of cultivation of the crops coming in rotation will depend upon the season in which rice is grown.

Ganjam district.—In the dry lands, dependent absolutely on rains, the rice is grown during the rainy season and the land remains fallow for the rest of the year. In wet lands the following rotations are practised :—

	Season	Crops grown	
1	June–September ..	*Ragi*, sunnhemp or *gogu* for fibre.	
	September–December ..	Rice.	
	January–April ..	Green-gram mostly, and to a certain extent black-gram also. These are sown either in the standing rice crop as in the south of the district or after ploughing the land as in the north where rains are more certain.	
2	July–December ..	Rice.	
	February–April ..	Gingelly.	
3	September–December ..	Rice ..	Area adopting this rotation is very limited.
	April–August ..	Vegetables ..	
4	First year	Sugarcane ..	Area adopting this rotation is very limited.
	Second and third years (July to December).	Rice ..	
	Fourth year	Sugarcane ..	

Sometimes in parts of Chicacole taluk, *samai* (*P. miliare*) is sown in wet lands anticipating some grain produce, if rains are late. If, however, rains set in early, the *samai* crop is puddled in as a green manure and rice is planted.

Vizagapatam district.—Rice is grown here both in garden lands and wet lands. In wet lands where the land is low lying only one rice crop is taken in the year but in other respects there is no difference in the cropping practice between garden and wet lands. A large number of crops is grown in rotation with rice. There is a large area under sugarcane in this district and wherever cane is not grown, three crops are taken in the year from the same land. The three seasons of the year are:

(1) early (*punasa*)—March to June,
(2) main (*pedda panta*)—July to December, and
(3) late (*pyru*)—December to April.

A large number of crops is grown in each of the early and late seasons. *Cumbu*, *ragi*, gingelly, maize, Bimlipatam jute, and onions are the crops grown in the early or *punasa* season. Rice is the main crop of *pedda panta* season. *Ragi*, gingelly and onions are grown in the late *pyru* season. One of the commonest rotation is *ragi*, rice and gingelly. In parts of the district indigo is grown mixed with gingelly in the late season after the harvest of rice. When gingelly is harvested away, indigo spreads on the land and when ready, is cut and carted to the indigo factory. In these areas there is thus no *punasa* crop but, the rice crop is planted early which coming after the indigo crop and also getting the indigo refuse as manure, yields very well.

Godavari district.—There are three portions of this district: the Western, the Central, and the Eastern delta, which all grow rice extensively. The rotation practices are not very different in the three tracts except that in the Eastern delta, sugarcane forms one of the rotation crops, its area in the other two deltas being insignificant. The rotations are different for the dry lands and the wet lands. In the dry lands, in the first year, the dry rice, *budama*, is grown either as a pure crop or mixed with red-gram, cotton, *gogu* or sunnhemp. In the following year, there is no rice on the land but gingelly is grown between June and September, and crops like *cholam*, bengal-gram or horse-gram between October and February. In the wet lands, rice occupies the land between June and December followed by sunnhemp between December and February. The land generally remains fallow between February and June, or sometimes a gingelly crop is taken between January and April. In years when the area gets its turn for growing a second crop of rice, it occupies the land between February and May.

Kistna district.—This district also contains two portions, the Western and the Eastern delta. In both the deltas, only one crop of rice is grown in the year, the varieties grown being of a

longer duration than those of the Godavari district. In both the deltas, rice occupies the land between June and December. In the Eastern delta, after rice, sunnhemp is grown on half the area of each holding for fodder purposes, and in the other half, black and greengrams are grown for the grain. Recently the practice of growing *pillipesara* for fodder as well as for green manure is on the increase. In the Western delta, there is a catch crop of sunnhemp for fodder, or horsegram for grain, that follows rice. The land in both the deltas remains fallow between March and June.

In the saline sandy soils of the Coastal tract, and the saline black clays of the Collair borders, rice occupies the land from June to November, and the land remains fallow for the rest of the year. In the better portions of the soil, sunnhemp or pulses are also grown in the off-season. In parts of the Western delta, known as the Tungabhadra bed, which consists of rich alluvial soils over a bed of sand, turmeric is grown extensively in one year and this is followed in the next year, by either dry *budama* rice, drilled along with redgram or other crops like maize, chillies, and groundnut.

Chingleput district.—In Chingleput there is practically no rotation in wet lands, the rule being, rice followed by rice. However, wherever rice is grown under well irrigation, a crop of *ragi* or gingelly is grown, in the hot weather. This obtains practically in every district where rice is grown as a garden crop as in North Arcot, Salem, South Arcot, Madura and Ramnad. The crops grown in rotation are several and varied. Cotton, *cholam*, tobacco, *cumbu*, onion, etc., are some of the other crops, besides *ragi* and gingelly that come in rotation with rice.

In parts of South and North Arcot districts, there are extensive areas under sugarcane also in wet lands, which comes in rotation with rice.

Tanjore district.—In the Tanjore district, there is practically no rotation adopted, the land remaining fallow after the harvest of rice from February to June. In some localities pulses like green and blackgrains are sown in the standing rice crop. Due to departmental propaganda the sowing of *kolinji* (wild indigo) or indigo mixed with grams for green manuring purposes is gradually becoming popular.

Trichinopoly district.—In parts of Trichinopoly district where water-supply in the Cauvery is available for nearly ten months in the year, plantain and sugarcane are grown in rotation with rice in wet lands.

Madura district.—The wet lands of the Periyar valley in Madura district adopt no rotation, rice being the only crop. The growing of green manure crops like *daincha* is slowly coming into vogue.

Tinnevelly district.—In parts of the Tambraparni valley of the Tinnevelly district in single-crop lands which grow only a *pishanam* rice crop during September—March, crops like field beans and *cholam* are grown in the *kar* season, June to October. Even in the double-crop areas, in certain parts, a crop of *senna*, gingelly, black or greengram is grown after the harvest of the *pishanam* rice.

Coimbatore district.—The wet area of Coimbatore district is comparatively small, but wherever facilities exist, plantain or sugarcane is rotated with rice. In certain areas with a favoured water-supply where growing of two crops of rice was the rule, the early first crop is now being replaced by a groundnut crop. After the harvest of groundnut, the haulms are all puddled in as manure for the long duration *samba* crop.

Malabar district.—In Malabar, in the double-crop areas in the valleys and in the single-crop terraced lands on the slopes of hills, rice follows rice, except for a precarious catch crop of cow-pea in the former, and horsegram in the latter. Even if no grain is obtained from these catch crops they are useful as green manure for the following main crop.

In *modan* lands grown with dry rice, a regular rotation is practised. These lands are naturally very poor in fertility and have to be rested for two or three years after a year or two of cropping. The *modan* dry rice occupies the land from April to September. This may be followed by gingelly, blackgram, or sweet potato. In some years *samai* may take the place of dry rice. In the northern taluks of the district ginger and tapioca may also be grown in rotation with rice.

South Kanara.—The rice lands of South Kanara are not very different from those of Malabar except, that the water-supply is more copious. Growing of horsegram or other pulses like greengram after rice in both single and double crop lands is more common here than in Malabar.

CHAPTER VII

Implements

Plough.—Because of the very nature of the cultivation practised, the number of implements which have to be considered in connection with rice growing is not many. The one universal implement used all over the country is the ordinary wooden plough. The plough used in dry ploughing is of course heavier and bigger than the one used for the wet ploughing.

The main principle involved in the wet cultivation of rice is puddling the soil with water, i.e., breaking the soil to a few inches depth into fine particles and what is desired is a sort of churning action. As long as the field has been flooded and the soil has soaked thoroughly, the first ploughing only breaks the soil and mixes the mud particles with the water. By repeated ploughings, the mud is broken into finer and finer particles which are left suspended in the water. In addition to the actual ploughing, the trampling of the plough animals and the driver also contributes to this breaking. While for dry land ploughing, the inversion of the soil obtained by a mould board plough is important, it is not so in puddling a field, but still it will be useful to use a mould board plough for the first ploughing which helps in burying the weeds growing on the soil surface. A number of small mould board ploughs useful for wet land ploughing are now available, e.g., the Hindustan, the Cooper, etc., and their usefulness has been recognized in certain rice tracts though the prices of these as compared to the wooden plough are still beyond the means of many rice cultivators. After the weeds have rotted sufficiently, the puddling operation starts and for this the plough is just as good or as bad as any other implement available in the country. The depth of puddle is important and the deeper the puddle the bigger is the crop. This can be easily seen by the rank growth of the crop wherever there has been any trenching done previous to the rice crop. The country plough is also used for ploughing broadcast fields to uproot weeds and thin the crop. A triangular harrow can also be used for this purpose.

A harrow-like implement with a number of teeth attached to a wooden beam just as is used in parts of Burma and Central Provinces, may profitably be used for puddling rice soils, but no trials have been made in Madras. An implement called 'settun' a sort of mower used in Burma to cut the grass from the rice fields before ploughing, was tried in the wet lands of Coimbatore and Aduturai but it was found too heavy and unworkable in these soils.

While for dry rices all that is required is harrowing after sowing the seed, the cultivation of the wet rice involves good preparation of transplant fields as well as seed-beds.

Levelling board.—This serves an important purpose in levelling the field after puddling. It also compacts the mud to a certain extent. There are two kinds of levelling boards, one a flat heavy plank with a handle attached, and the other a beam with a V shaped groove cut deep into it. Where the mud has to be moved from one portion of the field to another, the latter serves the purpose better, as the hollow portion when dragged against the mud moves it more effectively. Even the former can be made to move the earth by the driver holding the handle up and keeping the plank in a slanting position but this gives an additional strain to the driver. If soils are not too deep the driver stands upon the levelling board as it moves, so that the compacting and levelling is done more satisfactorily. The levelling board is usually used only in the preparation of seed-beds where a good levelling is much more important than in the transplant field. The use of the levelling board in the transplant field will certainly be advantageous and it does not entail too much of additional cost. In certain parts of the delta where the soil becomes very loose on wetting, no ploughing is practicable, and stirring of the soil by coolies with their feet and levelling are the only operations attended to before planting.

Drill.—For dry rices which are drilled in parts of Chingleput, Kistna and Godavari the ordinary seed-drill is used, but no harrows are used for inter-cultivation.

Water-lifting implements.—In garden cultivation of rice, water has to be lifted from wells. The most commonly used device is the simple mhote worked by bullocks as in Salem and Madura districts. Where the lift is only a few feet from the surface, the ordinary *picottah* is used. This is the most common method of lifting water in North Arcot and Vizagapatam districts. It may be a single *picottah* worked by a single man with a counter-poise at the other end of the oscillating beam, the capacity of the bucket being not more than three or four gallons; or a bigger one with a bucket of eight to ten gallons' capacity with two or three men walking up and down on the oscillating beam besides the man actually handling the bucket standing over the well. The picottah is really a very efficient device for lifting water, and is even better than the bullock mhote for small lifts.

In wet land rice cultivation, the irrigation systems are so designed that water is generally directly let into the fields. But it may so happen that under certain special circumstances the level of the water in the canal or tank will go below the level of the fields in which case water may have to be lifted by a few feet. Where the lift is small, say, 2 to 3 feet only, the one implement commonly used in the south is the swing basket. Two men work

this standing on either side holding the ropes attached to the basket. The capacity of the basket is not more than two to three gallons and it is fairly efficient. Then there is the trough lift known as '*kareim*' used in Kistna and Godavari districts to lift water to small heights of a few feet. The trough is made of a hollowed-out palmyra trunk or wooden planks but recently iron troughs have been introduced in its place. Generally three to four men are employed to work this.

There is the water wheel or *chakram* which is mostly used, not to lift water on to the land but to lift it off, i.e., to drain low-lying swamps sufficiently to take a crop of rice therefrom. It is a paddle wheel with twelve paddles of neat construction, working in a slot, and made to revolve by means of the feet; the slot is provided with a shutter which can be let down before the wheel as soon as work stops, to prevent water flowing back again. These water wheels were generally in use in parts of Malabar but of late they have been replaced by oil engines.

The Archimedean screw is exceedingly efficient for low lifts, and has been introduced in parts of Kistna district, for lifting water on to the lands just above ordinary irrigation level. It consists of a cylinder, one end of which is made to dip under the surface of water. Within the cylinder is a spiral portion, the effect of which is gradually to screw the water upwards when the cylinder is rotated. The screws are of different sizes of 5 to 9 feet long and can be used to lift water to heights of 2½ feet to 5½ feet. A 6 feet machine can irrigate nearly one acre of land with 6 inches of water in 6½ hours if the lift is below 2 feet.

Lastly there are the oil engines which are efficient and more economical for irrigating large areas. The use of small oil engines for irrigating rice fields, ten to fifty acres in extent can be seen in parts of Chingleput district and in Kistna district on the borders of Collair lake. One of the largest oil-engine installation in Madras is that used for pumping water from the Kistna river near its mouth to irrigate the rice fields in the Divi island. The installation consists of eight Diesel oil-engines, each of 160 brake-horse-power, and each driving a 39 inches centrifugal pump. The area irrigated by this installation is at present about 30,000 acres but the area can be increased to forty or fifty thousand acres.

There are no machines of any kind used in harvesting or threshing the crop. The cost of agricultural labour is still cheap and with the most intensive method of rice growing under swampy conditions by enclosing small portions of the area with water-tight bunds, there is very little scope for introducing harvesting machinery. The cleaning of the grain is also done by human labour, the winnowing machine being absent even in big holdings. The storing of the produce has been already dealt with and does not involve the use of machinery of any kind.

CHAPTER VIII

Rice-milling

Hand pounding of rice.—For consumption the grain has to be freed of its husk. The time honoured practice of pounding rice with the ordinary wooden pestle and mortar is well known. This is done usually by the womenfolk, and two women can husk and clean about 150 lb. of grain in a day of eight hours. There is an improved type of this to be found in parts of Malabar and South Kanara where the feet are used instead of the hands. This consists of a wooden beam, 6 feet to 8 feet long and works on the see-saw principle fixed to a pivot. To one end of the beam is fixed a short pestle and this drops into a wooden mortar, fixed in the ground. The mortar is filled with the grain and the worker treads on the beam end opposite to the one to which the pestle is fixed and this lifts the pestle to 2 or 3 feet above the mortar. By suddenly releasing the pressure on the beam the pestle drops with force into the mortar and pounds the rice contained in it. This is usually worked by men, and is more arduous than the ordinary pestle and mortar though much more efficient. After a certain amount of shelling is done the grain is removed from the mortar, the separated husk winnowed away and the unshelled grain put in again into the mortar for pounding. When the whole shelling is finished the rice is polished in the same mortar to remove the bran. Such hand-pounded rice can never get the same polish as that of a machine-milled rice. In some places as in South Kanara district, the tenant gives the landlord's share as rice in neatly packed straw bundles, the rice pounding serving as an off-season work for his family. This indigenous method of pounding rice is becoming practically extinct except in the interior portions of Malabar and South Kanara. Whether the introduction of machine milling has been all to the benefit of the rice consumers will be dealt with later. Because of the hard and tiresome nature of the hand-pounding and due to the rapid increase in the number of power-driven rice hullers even in the rural parts of the country, it has become difficult to get labour for pounding rice. Even the coolie classes who get wages paid to them in kind, usually take it to the nearest mill to get it pounded.

Power milling.—Milling rice by power is now an established industry in the province, there being quite a number of mills in Tanjore, Kistna and Godavari districts. The industry has probably not developed on altogether desirable lines. In the chief milling districts, the industry has been detrimentally affected owing to the competition arising from an excessive number of mills. Few of the mills are operated continuously at their maximum capacity. The development has been on the installation of the single huller

mills driven by oil engines. These were considered at first to be a good beginning of rural industries and it was hoped it would pave the way for the establishment of large scale factories. Unfortunately, the number of these has become so many that in Tanjore district where rice milling was at first a most remunerative business, it has resulted in several of the mill owners losing heavily.

There is also a fair number of large scale cone mills working on the Rangoon system in Tanjore, Kistna and Godavari districts, but the small hullers are to be found practically in every district, even in rural parts. While in Tanjore district, the large scale steam-driven mills came in later after the single huller type, in Kistna and Godavari districts, large scale mills have evolved directly from the hand milling stage. It is probable that either the spirit of enterprise is more fully developed in the Telugu districts or that there is a larger concentration of capital in the hands of individuals which enables them to carry on industrial operation on a large scale. Probably the availability of cheap water transport through the canals in these districts has also contributed to this enterprise.

Milling in big mills.—In the big mills, the preparation of the raw rice consists in the grain being first delivered into the hopper of the mill and in passing through the first preliminary cleaning machines, immature grain, chaff, stones, grit and mud are removed. The cleaned produce is then taken by elevators to the disc shellers. After shelling, the shelled grains and husk are separated by blowers. The husk obtained is used as fuel for the boilers generating steam. The rice obtained is passed through hullers for polishing once, twice or even thrice. In order to avoid too much of breakage in the polishing process, an interval extending from three days to a fortnight is allowed between any two operations. Thereafter the grain is allowed to pass through sieves for the separation of broken grains. Most of the coarse rices prepared are not highly polished as they are required mainly by the poorer class of people. The fine rices, however, are highly polished as the well-to-do people go in for only well-polished rices. In some of the rice exporting countries they have different trade names for the rices according to the extent of polish given. Raw rice prepared from freshly harvested grain is poor in quality and rice from grain that has been stored for some time is always preferred. There are also varietal differences with regard to the quality of rice, the *kar* varieties of shorter duration giving always rice of a poorer quality than the *samba* varieties of long duration.

Preparation of par-boiled rice.—In the preparation of the par-boiled rice the nature of the grain used is not of importance as in the case of raw rice. The conditions affecting quality in par-boiled rice are the time of steeping, the water used (hot or cold), renewal of water during steeping, the period of steaming, and the amount and nature of drying given before milling.

The grain is first steeped in water in masonry tanks of the capacity of 300 to 400 bags, for a period varying from 24 to 72 hours according to the nature of the grain. New and wet grain requires a longer soaking period than dry and old grain. In the Circars where steeping is done in warm water, the soaking period is restricted to 24 hours. In Tanjore, cold water is used with a longer soaking period, and the water is changed every 24 hours. The advantages in the longer soaking in cold water are stated to be reduction in the percentage of breakage and a higher percentage of rice to paddy. But the colour and flavour of rice get affected unless care is bestowed to change the water at intervals. The steeped grain is then conveyed to wrought iron drums of 20 to 50 bags capacity, where it is subjected to live steam under pressure for 10 to 12 minutes. The steamed grain is removed quickly and is either spread in thin layers for drying on special floors or allowed to remain in heaps for some time according to the variety and the market for which the finished product is intended. In the case of *vadan samba* variety of Tanjore district, it is said that it should be kept in heaps for some time as otherwise breakage results in milling. In the drying floors the steamed grain is exposed to the direct rays of the sun for about eight hours or so, being raked over at intervals until dry. The drying has to be done with care as either overdrying or insufficient drying affects the milling qualities. The milling of the par-boiled grain is similar to that already described for milling raw rice.

Recently two changes have been introduced to get over some of the defects in the par-boiling process in the big mills. In the Circars in addition to the usual steaming of the grain after soaking, the dry grain is first steamed under pressure for 10 minutes and then conveyed to the soaking tanks filled with cold water and then allowed to remain there for 24 hours. Though this extra steaming process entails an additional expenditure of an anna and a half per bag, the keeping quality of rice is enhanced and the produce resembles rice prepared from old grain. In the Tanjore district the large steaming tanks are now being replaced by smaller ones to facilitate the expeditious removal of the grain for drying as any delay is said to affect the colour of milled rice obtained. Opinions vary among the millers about the effect of the variations in the practices of soaking, steaming, drying, etc., on the quality of rice. They are mostly empirical and there is no scientific background for them.

The method of par-boiling grain in small mills differs slightly from the one described above. Here the grain is first soaked in tubs or masonry tanks for 18 to 24 hours and then conveyed to rectangular hot iron pans fitted with iron gauze inside to allow space for steam to be generated. The soaked grain is directly boiled over fire at atmospheric pressure for two hours. Then the grain is spread out immediately to dry in the sun and under shade in the night. In certain places they provide even roofs over the drying floor during nights as it is supposed to improve the quality of rice.

Milling in small mills.—In the small mills there is no separate shelling. Here husking and polishing are both done in one operation. There is no separate polisher, the grain being pushed through twice through the hulling cylinder. There are some inherent defects in the small mills as compared to the big mills, which consist of a sheller, huller, aspirator and blower. The percentage of finished rice obtained is poor, the cost of renewals excessive, and the husk is often wasted. Further the breakage of grain is considerable and the appearance and finish of the rice distinctly inferior. Also owing to the absence of any means of cleaning or separating the grain, the husk and bran obtained from these mills remain together and consequently fetch a very low price as cattle feed. The fuel value of this mixed by-product is also low and it is often thrown away, the demand being small. The pure bran obtained from the big mills commands a high price and adds to the receipts.

Colouring finished rice.—In the preparation of raw rice according to the requirements of special tracts where a preference is shown for rices with either a yellowish or reddish tinge, the millers add some colouring matter during polishing, turmeric or yellow ochre for the yellow tinge and red ochre for the red tinge. The par-boiled rice before it is bagged is sometimes mixed with a white flour which acts as an absorbing agent of moisture and gives the rice an attractive whitish colour. The rices of the European markets particularly those coming from Italy, Spain and America, have all got a beautiful shining lustre and translucence which they do not naturally possess. It was pointed out previously that special precautions are taken in the harvesting, threshing, and drying of the produce to improve the quality of the rice obtained. But there is also a special process of artificial glazing that is adopted. The finished polished rice is treated with a mixture of talc and glucose. In Italy, the so-called 'oiled rice' is prepared by treating the polished rice with a fine odourless oil which imparts a lustre to the kernel. Sometimes it is usual to add a small quantity of ordinary blue, as used in laundries, to accentuate the whiteness of the product.

Costs of milling.—The cost of husking rice by the hand-pounding method varies from place to place according to the local labour charges. Near big urban centres where labour wages are high, the husking charges will be more and in some places it may even be impossible to obtain labour for this work. It will be roughly 8 to 12 annas to mill a bag of whole grain. In some places the charges are paid in kind, at so many measures of clean rice for a bag of whole grain. The coolies that do the husking invariably get a share of the broken rice obtained.

In the small mills, the charges vary from place to place according to the location. If the mill is within a town, a higher rate is charged than when it is in a rural part. The charges of milling

in these mills vary from 6 to 8 annas per 150 lb. of whole grain and all the husk, bran, etc., are returned to the producer. In some of the mills situated in rural parts, the miller retains the husk and bran and charges proportionately less for milling.

In the big mills of Godavari the charges for preparing par-boiled rice come to about seven annas per bag of 164 lb. of rice. In Nellore the charges vary from Rs. 25 to Rs. 30 per 100 bags of grain. In Tanjore the charges are higher, amounting to nearly 12 annas per bag. The milling charges, to a certain extent, depend upon the saleability of the by-products of the mill.

Rice—How consumed.—The consumption of rice takes place in this province in two forms, one as raw rice and the other as par-boiled rice, and they vary in the different parts of the Province. In Tamil districts the consumption of raw rice is generally confined to the well-to-do classes while all the labourers and poor classes eat only boiled rice. In the Circars and Ceded districts however, all classes of people irrespective of their status, use mostly raw rice. In Malabar, the consumption is exclusively of par-boiled rice with all classes of people. In the case of the production of raw rice, the grain in husk is taken straight to the huller whereas in the case of par-boiled rice the grain has got to be first boiled and then dried before milling. Poor people who wish to mill small quantities of grain for their consumption take it to the small mills either as fresh grain or as par-boiled grain according to their requirements and get it milled for a definite charge levied. In the case of the large mills, however, the millers themselves, either on their own or on behalf of rice merchants, take the raw grain, par-boil it and then prepare boiled rice. Recently in the southern districts, even the small millers provide facilities or undertake to par-boil the grain first and then mill it, there being a separate charge levied at so much per bag for the par-boiling process. While almost all the big mills in Tanjore district prepare only boiled rice, most of the mills in Kistna and Godavari districts prepare raw rice.

By-products of the mill and their uses—Husk.—There is the outer husk which comes off first and this is absolutely useless except as fuel. It contains a very high proportion of silica and can hardly be used as feeding material for live-stock. In the big mills this is first removed by shelling and is exclusively used as fuel for the steam engines working the mills. There would still be a large amount of this left over after using as fuel, and it is a common feature to see large accumulation of the material round about mills. It has been demonstrated in Coimbatore that this husk can be converted into activated charcoal, useful in the manufacture of good cream coloured jaggery.

Bran and meal.—The grain after the removal of the husk is usually brown and contains a thin inner husk covering the kernel.

The inner husk is called the bran layer and is firmly attached to the grain. Polishing of rice consists in the removal of this layer partly or completely according to the degree of polishing given. In hand-pounding, the removal of the layer is never complete. The bran obtained by polishing is a highly nutritive substance containing proteins, oils, etc., and is of great value as a feeding material for livestock and is sold as such by most of the mill owners thus getting them a monetary return. This is used even as a human food, particularly as a remedy for beri-beri. During the polishing process, there is a large amount of ' germs ' from the grain which get removed along with the bran. The bran and the germ contain the most nourishing properties of grain. As the germ is rich in oil, care must be taken that the meal containing this is not stored for too long a period as it quickly gets rancid. In the small single huller type of mills, however, the bran and the husk come out together in a powdered condition and unless the broken husk can be sieved away from the bran, it is not safe to use this mixture for animal food. It is reported that digestive disorders are common in animals fed on this mixed material.

Broken rice.—In milling, whatever way it is done, there must always occur a certain amount of broken grain and this has to be separated from the rice. This is what is known as broken rice, and the amount and grade of it will vary according to the kind and quality of grain milled. In the preparation of the par-boiled rice, the quantity of broken rice is relatively small, as the process of par-boiling the grain hardens it and makes it less subject to breakage. In fact most of the short duration varieties are unfit to be milled as raw rice, and are almost invariably par-boiled before milling, the preparation of raw rice being confined to the better class, long duration rices. Even when coarse rices are milled raw, no attempt is made to eliminate the broken rice, firstly because it will increase the milling charges and secondly the produce is intended mainly for the consumption of poor people to whom cheapness is the main consideration. Moreover, in Madras, the rices are milled separately according to varieties as only particular varieties are grown in particular localities. Since there is no mixing of varieties in milling, there is very little breakage and hence the quantity of broken rice produced is small. There is no regular output or demand for locally obtained broken rice. In other rice-exporting countries like Burma and Siam, the milled grain consists of mixtures of varieties leading to a good amount of breakage in milling. Since the rices produced here are put in the international market, the scrupulous elimination of all broken grains is important and consequently there is a fair amount of broken rice available for putting on the market. While the higher grades of these broken rice may compare favourably with rice of finer varieties, the general output is a by-product that can be disposed of for what it will fetch.

This broken rice is largely consumed as such by the poorer classes, mainly labourers, and it is also utilized by the Indian restaurants and the innumerable tea shops where it is ground into flour for making cakes. A small quantity of inferior broken rice is used in the preparation of *conjee* required by washermen and weavers for stiffening purposes. In other countries the broken rice is used for the manufacture of rice flour, in the brewing of beer for which it finds a ready sale in the continent, for the manufacture of starch for which it is well suited, and for the production of alcohol. In French-Indo-China and other places there are large distilleries devoted to the manufacture of spirit and allied products on an extended scale, the raw material in all cases being broken rice. The famous Japanese spirit *sake* and the more potent Chinese *shemshu* are obtained by distilling broken rice. It is also used for a similar purpose in the Dutch East Indies. Rice flour can not only be used for the preparation of cakes and bread but is also useful in the preparation of patent foods and toilet powders.

Classification of rice in the markets.—Apart from the botanical classification that is referred to later, the rices that come into the market can be classified according to the following grain characteristics all of which are concerned with the milling :—

(1) Size of grain—whether fine, medium or coarse.
(2) Colour of rice—whether red or white.
(3) Texture of rice—whether hard and flinty or soft and mealy.
(4) Milling qualities.
(5) Outturn of rice to grain.

Size of grain.—The size classification is based on the ratio of the breadth to the length of grain, the greater this ratio, the finer being the rice. The finer rices are preferred by the well-to-do classes and fetch a better price in the market. The size is probably not important in the case of par-boiled rice which is the form in which most of the rice is consumed by a large percentage of the population. Though the size of grain may be a varietal character, it is also influenced by seasons and soils. A finer variety tends to become coarse when cultivated continuously in rich heavy deltaic soils. As examples of such a change, the case of GEB. 24 in Godavari and the *Nellore samba* in Tanjore may be mentioned. This tendency to become coarse will naturally affect any premium it might be getting in the market. *Gunupur sannam* grown in the Agency tracts is considered finer and fetches a better price than the same grown in the plains of Vizagapatam district. Similarly if a rice is grown on an exhausted soil, the size of the grain tends to become smaller.

The rice may be classified into coarse, medium and fine. Varieties, *mypali* of Vizagapatam, *basangi*, *konamani*, *garika-sannavari* and *atragada* of Godavari, *kusuma* of Kistna, *vadan-samba* of Nellore and Chingleput, *kar* and *ottadan* of Tanjore,

manavari and *kar* of Tinnevelly, *kayama* and *thavalakkannan* of Malabar, all belong to the coarse group. The distinction between medium and fine rices is not so sharp, but still as examples of medium rices may be mentioned *ratnachudi* of Ganjam, *krishnakatukulu* and *akkullu* of Godavari, *molagulukulu* of Nellore and *anaikomban* of Tinnevelly. As examples of really fine rices, *GEB*. 24 of Coimbatore, *vankisannam* of Kistna, *sirumani* of Tanjore, *jeeragasamba* of South Arcot and Tinnevelly may be mentioned. Among the fine rices are included not only those which are thin and long but also short roundish grains.

Colour of rice.—So far as colour is concerned there are only two grades recognized, red and white. There is also a black rice and also rices of other colours that could be produced experimentally by crossing, as brown, grey-brown, gold, light-red, etc., but they are not all important. The colour of rice is confined only to the fruit coat or the bran layer and even the deeply pigmented rices as the black can be made to appear white by good polishing. There is no rice where the kernel inside is coloured. As regards red and white rice, white is generally preferred although red is considered more nutritious. This again varies with the tracts. Most of the varieties grown in Malabar are red-riced and so also a number of them grown in the Tamil districts of Tinnevelly, Madura, Tanjore and Chingleput. The red rices produced in the Province are generally consumed by the poorer classes of people, while in Malabar, most people irrespective of their status, use only red rice. In ordinary hand-milling, the red rice can never be polished, into white. In machine-milling if the colour has got to be removed, the polishing will have to be done very thoroughly resulting in a large amount of loss both by breakage and by reduction in the percentage outturn of clean rice. Even then such a highly polished red rice can be easily differentiated from white, the tinge of redness being always present. The presence of red rice in a white sample is an objectionable feature and the percentage of it often determines the value of the sample. The larger this percentage, the more is the polishing necessary and hence more is the loss in milling.

Texture of rice.—The mealy and soft grains can be differentiated by the presence of the white 'abdomen' and these break easily while milling. The harder and pearly grains not only suffer less by breakage in milling but they also take the polish better than soft grains and hence obtain a better price in the market. As a general rule, all the short duration *kar* varieties of the province are soft and have to be converted into par-boiled rice. While this may mainly be a varietal character, agricultural practices do seem to have some effect on it. Garden-land produce, i.e., produce obtained from fields under well irrigation, is considered harder than the produce grown in the deltas. The stage of the crop at which it is harvested and the method of storing the produce as was pointed out already, also influence the texture of the grain.

Milling qualities.—Apart from varietal differences, the milling qualities depend upon the size and shape of grain, and on the conditions of harvest and storage. Thin long grains break more readily in milling than big bold or small round grains. The shelling is very much easier in the round grains. Almost all the important commercial rices of Japan, Spain and Italy belong to the roundish type. The milling qualities can be improved by adjusting the harvest practices. It is the difference in the harvest practices that makes the *nellore samba* of Nellore better than the same rice grown in Tanjore. The presence of grains of different sizes particularly affects the milling, but this is not of importance in Madras as there is never a mixing of varieties before milling.

Outturn of clean rice to grain.—The percentage of clean rice to whole grain is essentially a varietal character although the presence of chaff and half-filled grains in the sample contribute to a low outturn. Excessive delay in harvest gives rise to a high percentage of breakage in milling raw rice. The varieties like *molagulukulu* and GEB. 24 may be mentioned as examples of those that give a high outturn of rice to whole grain. Tanjore *sirumani* variety also gives a higher percentage of rice to whole grain than others. Thin long grains like *banku* give rather a poorer percentage of rice to whole grain than others. Since it is the quantity of whole clean rice that is taken into consideration, any rice that breaks much during milling must give a low percentage of rice. The percentage determined by actual small husking tests will be different from what is obtained in the big mills. It is usually taken as about 50 per cent. by volume, and as about 66⅔ per cent. by weight. Under laboratory conditions among the number of varieties tried in Coimbatore mere shelling, i.e., the removal of the husk alone, gives 55 to 61 per cent. by volume and 65 to 76½ per cent. by weight of rice to whole grain.

CHAPTER IX

Food Value of Rice

Losses due to milling.—Rice, as was stated already, is the staple food of more than half the population of the world. There is no doubt that the produce as obtained from the field freed from the husk only, is nutritious, easily digested, easily prepared and more than all, is relatively cheap in the place of production. The grain contains besides, a large amount of starch, protein, fat, mineral and fibrous matter and most important of them all, the nerve recuperative vitamin B. The protein of rice from the nutrition point of view is considered superior to that of wheat or maize, resembling more that of animal tissues. But the grain with all these contents is quite different from the one that is ordinarily consumed. It is now well known that the food value of the grain is very much lowered by subjecting it to machine-milling and good polishing. The craze for the nice-looking white rice is one of the evils of modern civilization, where quality is forsaken for the sake of appearance. It is the bran layer that contains this vitamin and also most of the protein, practically all fats, minerals and phosphorous compounds. It was pointed out already that in machine-milling this bran layer is removed completely. It may be taken definitely that the better the polish and appearance of the rice, the less nutritious it is. The polished rice contains nothing but starch, besides a small quantity of protein, oils and mineral matter. The disease '*beri-beri*' common with the rice-eating oriental nations has now been definitely traced to the lack of this vitamin B, in the food taken by the people. It is prevalent only with people whose chief diet is machine milled raw rice, particularly when it is not accompanied by foods richer in protein as fish or pulses. So long as people were eating only hand-pounded rice where the complete removal of the bran layer is impossible, this nutrition deficiency disease was not known. Food reformers of modern times have been preaching to people to go back to hand-pounded rice but the difficulty is mainly with the scarcity of hand-milled rice on the market. But it is quite possible to put on the market what is known as 'brown rice' which is nothing but the shelled grain with all the bran layer intact and this Japan is already doing. But once the people are used to eating highly polished rice, they cannot easily take to unpolished rice. The unpolished rice is slightly more difficult to cook and apart from its brownish looking colour, when cooked, it opens out without retaining its shape and is rather rough to the tongue. But it is all a question of what one is used to, and if one is accustomed to eating brown rice, he will have the same

difficulty to change over to polished rice. What is required now is a vigorous propaganda, particularly among the educated middle-classes to make them eschew polished rice. When once the demand for brown unpolished rice is set up, the supply in the market will naturally follow. The production of brown rice will be possible only with the large mills provided with shellers. If necessary a small amount of polishing can also be done in these still retaining much of the nutritive ingredients.

Losses in cooking.—Besides the loss in the nutritive value of the grain by milling and polishing there are also further losses occurring in the way the grain is usually cooked and eaten. Before cooking, the rice is first washed thoroughly twice or thrice in clear water, which removes all traces of bran that may still be sticking to the grain. Again the rice is boiled with more water than what the grain could absorb when swelling, so that there is a certain amount of thick supernatent liquid with probably some mineral matter, proteins and starches dissolved in it, and this is drained off from the cooked rice. The preparation of rice in the modern cookers is an improvement and prevents this evil.

That the disease *beri-beri* is due to the loss of the vitamin B contained in the bran, is apparent from the excellent results of cure obtained by the patients taking this bran mixed in water. Though Japanese people are also using polished rices, they try to make use of the nutritive elements of the bran. They have a method of preparing green pickles with cabbage leaves and other greens to which the rice bran is also added first. After some time even when the bran is washed out, the leaves are found to have absorbed the vitamin contained in the bran and thus its valuable principle is not lost.

It is often stated that the general poorer physique of the average South Indian whose diet is mainly polished rice cannot be due to this inasmuch as the Japanese are also mainly rice-eaters. But in such a statement one important point is ignored in that in the Japanese diet, fish often comes in, which is not so in the case of the South Indian diet. Fruits, vegetables and pulses also do not form a necessary part of the South Indian diet except probably with the well-to-do classes.

Par-boiled rice.—The occurrence of the *beri-beri* is, however, not noticed with people who consume par-boiled rice. It is practically absent in Malabar and parts of Tamil districts where most of the people take only par-boiled rice. The eating of the par-boiled rice along with fish and coconut which usually forms the dietary of the Malabar people, is probably the reason for the average Malayalee being better fit physically than his equal in other districts. In Madras, the occurrence of *beri-beri* was first noticed only in the Telugu districts, where the consumption of rice among all classes of people is in the form of machine-milled polished white

rice. That par-boiled rice is comparatively more nutritive than raw rice is recognized but why it should be so is not sufficiently understood. It is considered that some of the valuable principles in the bran layers diffuse into the endosperm during the process of par-boiling and do not get removed during milling and polishing. Food reformers might as well carry on propaganda recommending the use of par-boiled rice instead of raw rice. There will be no difficulty in obtaining high grades of par-boiled rice on the market, and it will surely be the next best thing to do if unpolished raw rice is not procurable. There will be in the case of the par-boiled rice, the brownish colour of the cooked rice and the peculiar flavour. It is only a question of foregoing appearance for the sake of better nutrition.

Variations in nutritive values of rice.—Very little is known about the nutritive value of the different rices. It is often stated that some rices are more nutritious than others but such a statement has no scientific foundation. Most of the rices that are consumed in the polished state differ very little in their chemical composition, although, definite variations in the amount of fat, protein and starch have been observed in the unpolished rices of different varieties. McCarrison has found by actual feeding trials that rices grown under dry or semi-dry conditions are more nutritious than the rice grown under typical swamp conditions. If it is possible to grow rice as economically under the former conditions as in the latter, it should prove advantageous. This would mean a complete alteration in the cultural practices usually adopted with this crop. Certain varieties of rice have been found to grow and give satisfactory yields as for example, the *basangi* at the Maruter station, under semi-wet conditions and if we could extend this, we would be producing not only more nutritious rice but also solving the difficulty of drainage problems where rice is to be grown in rotation with garden land crops.

Red rices are generally considered more nutritious than white rices. Recent work at Coimbatore has shown that it must be true. It is known that all the nutritive principles of rice are located in the bran layer. Sections of different rices have been examined at Coimbatore and it is found that the thickness of this bran layer varies in different varieties, and red rices have usually thicker bran layers. It is possible that even some of the white rices have got thicker layers than others and such rices must certainly be more nutritious than those with thinner layers. Though red rice may be looked down upon where high grades of polished white rices are concerned, it is nevertheless cultivated and its high food value appreciated, in particular districts, as Malabar and Tinnevelly. It appears that red rice is even preferred to white rice in parts of certain other countries like Ceylon, Madagascar, etc.

There are again differences in food value attributed to rices of different durations. Short duration rices are generally considered

less nutritious than long duration ones, unless they are converted into par-boiled rice. Whether the difference consists only in the cooking qualities or whether such cooking qualities are related to their nutritive values is not known. The process of chemical changes in the grain as it ripens in the plant in the field is being followed and any differences observed in such changes between an early and a late rice should throw light on this question.

Storing of grain was considered previously but very little is known about the relationship between nutrition and storage. Rice immediately after harvest is unfit for consumption as raw rice and has to be stored for some time, the period of storing depending upon the variety. Some varieties like GEB. 24 become fit for consumption much sooner than others of similar duration. If consumption of fresh rice is inevitable it has to be converted into par-boiled rice. What the changes are that take place during storage, is not understood and it is only recently definite investigations have been taken up by a special Bio-chemist at the Indian Institute of Science, Bangalore. That fresh rice is poor in quality is evident from its poor cooking qualities, its less wholesome nature for consumption bringing on digestive disorders, the smaller volume of cooked rice it gives, etc., apart from the difficulty involved in milling fresh grain without breakage. Probably during storage the process of ripening initiated when the crop is in the field continues and some of the complex carbohydrates are converted into simpler ones by the action of enzymes.

The amount of moisture present in the grain at the time of storage and the conditions of storage also influence such changes. Grains stored in air-tight receptacles become fit for consumption sooner than those stored with free access to air. Sometimes to hasten ripening, the grain is stored in underground air-tight pits and such grain after remaining in the pit for about two months gets the same cooking quality of grain nearly a year old in storage. The characteristics of old rice of good quality are,—it takes longer time to cook, absorbs larger amounts of water while cooking, does not get squashy unless the cooking is very much overdone and does not dry hard if left long after cooking. Regular storage experiments combined with periodical cooking tests have been undertaken in Coimbatore and these should throw light on this complicated problem.

As regards the materials used for glazing and artificial coating of polished rice, they are mainly mineral matter and have no food value. Generally rice is washed in water before cooking and this should remove all this extraneous matter. Even if it does not, the whole of the glazing disappears while the rice is being cooked. In the United States of America one of the Food Inspection Division directs that glazed rice shall be labelled in all cases with the name of glazing material used, and dealers add to the label the words "remove by washing before using."

There are two rice preparations that are very commonly used in the south, namely, the beaten rice and the puffed rice. The production of these is still a minor cottage industry in certain rural parts. Certain special varieties are chosen for the preparations as particularly suitable. The process of preparing these is so well known to every household in the country that there is no necessity to describe it.

Beaten rice.—In the case of the beaten rice, its value depends upon the extent to which the rice has been beaten. The thinner the beaten rice the better, as it easily soaks and becomes soft for consumption. Both red as well as white rices are used for this preparation according to the demands in the locality. South Kanara is the district where the best beaten rice is produced. It is a common article of food taken as it is, with a little jaggery and coconut by the poor people or soaked in milk or curd and spiced. It is a sustaining food and contains intact all the nutrients contained in the rice. It is only the valueless husk that has been removed.

Puffed rice.—The puffed rice is of two kinds; one is prepared straight from the grain in husk by frying it in a mud pot over fire. The rice here opens out. The other may be called pop rice and is prepared from par-boiled rice after salting it first. Here the rice keeps its shape but is spongy. The proportion of puffed rice to grain will be about six to eight times by volume. The puffed rice is a valuable invalid food when prepared into a porridge. Both the puff and pop rice are often made into balls with a little addition of molasses or *gur* and form the most common sweet of the poor, obtainable at every shop in the rural parts of several districts. Like beaten rice these also contain all the nutrient principles of whole rice and well prepared beaten and puffed rice can easily replace the imported and rather expensive breakfast foods like shredded wheat, force, etc., which are used by the educated middle-class people of the country.

Glutinous rice.—A word may be said about the glutinous rice. This rice known in Tamil as '*Puttu rice*' is grown in small quantities in Madras. It does not really contain gluten but the starch is present in a different form. It appears to be a very wholesome food and it would be profitable to make greater use of it. It cannot be cooked like ordinary rice but can be steamed which is the ideal way of preparing any rice for consumption. Mixed with a little sugar and shredded coconut it makes an excellent and sustaining food.

CHAPTER X

Rice Seed

Germination.—Quality of seed depends upon its germinating capacity. Rapidity and high percentage of germination are very important. The germination greatly depends upon the method of storing the seed. It is possible that in some cases the grain as soon as it is harvested from the field may give a satisfactory germination but it is more an exception than a rule. In a majority of cases the grain has to be stored for some time after harvest before sowing. Generally the grain intended for seed purposes is dried thoroughly after harvest and then stored. As was pointed out already the maintenance of viability of the grain depends upon the storing conditions. With the most common method of preserving seed in gunnies, the seed is liable to absorb moisture particularly if the period passes through a wet or rainy spell. If the quantity of moisture so absorbed exceeds a limit, the seed is likely to lose its viability. This is the reason for the seed of *garikasannavari*, the chief second-crop variety of Godavari, harvested in May, becoming unfit for sowing next January, as it has to pass through two wet periods in the meanwhile. This can however be satisfactorily avoided by either drying the seed at intervals or by storing it in air-tight receptacles such as metallic bins.

Testing germination.—A good stand of the crop cannot be obtained unless the germination is satisfactory. Instead of seeing whether the germination is satisfactory after the seed has been actually sown in the field, if a small preliminary test could be made of the viability of the grain, much of unnecessary loss might be avoided. A small sample of the grain intended for seed purposes may be drawn and sown in a pot or tray containing moist sand; the number of grains that germinate within the first three or four days out of every 100 grains sown represent the percentage viability of the grain. If the germination is more than 90 per cent. within the first four or five days, it can be taken as satisfactory. It may sometimes be argued that after making this test the quantity of seed to be sown could be increased proportionately, i.e., if a sample gives only 50 per cent. germination, the defect could be got over by using double the normal seed rate. This is not, however, quite a correct procedure as the germination in the field is quite different from the germination in a pot under laboratory conditions. The field conditions can never be uniform and it is impossible to get a cent. per cent. germination although the laboratory tests might have given this figure. Any seed which is only slightly defective in germination under the laboratory test, is likely to prove very much worse under

the field conditions. Any seed which gives less than 70 per cent. germination under laboratory conditions should never be sown if it could be helped.

Resting period.—When conducting germination test, we must take into consideration, the time when the grain was harvested. While some varieties of rice can germinate immediately after harvest, others require a resting period before they can germinate. The varieties that do not require the resting period are those which on occasions when the weather is wet or the crop is blown down at the time of harvest, begin to germinate in the head itself. These have to be harvested a little early. Generally short duration varieties are able to germinate soon after harvest without any rest as *swarnalu, garikasannavari, kuruvai,* etc. *Rasangi,* is however, an exception that it wants at least three or four months of resting period. Long duration varieties generally require a resting period of two to four months, Co. 3, however, being an exception to this. The knowledge whether a variety requires any resting period or not, can be gained only by actual test.

Tests made in Ceylon, Bengal and British Guiana, also point out that while early varieties hardly require a resting period, late varieties require a resting period of three to four months. In Ceylon even for the varieties that require a resting period, the cultivator increases the percentage of germination by smoking the seed, i.e., placing the bag of seed in the smoke of the kitchen fire. In long-aged rices which require about three months' resting period, smoking increases the germination percentage by about 10 to 30 per cent in the second month, but it ceases to have any effect after three months since the seed has had the required resting period by then.

Sometimes to improve the quality of the grain for consumption, the crop is cut even before it is dead ripe. When such grain is to be used for seed purposes it requires a thorough drying and even the ordinary resting period may be prolonged.

While the viability of the seed is controlled by the method of storage and the atmospheric conditions acting on it, under ordinary conditions of storage, the viability goes down after some time. Monthly germination tests conducted in Coimbatore showed that GEB. 24 seed maintained its viability in full for 13 months after harvest, after which time there was a steady decline to 80 per cent. after 24 months' storage, which figure was maintained until 33 months had elapsed from the beginning of the test. Co. 1 was good for 15 months, but dropped rapidly to 49 per cent. in 24 months. Co. 2 and 3 showed a little more variation and after 12 months, dropped rapidly. They showed only 20 per cent. germination after 24 months. There is thus a great deal of variation among the varieties. Generally it is the seed that germinates very quickly after harvest without a resting period, that loses its viability sooner.

Rate of germination.—Even among varieties harvested at the same condition of ripening, the rapidity of seed germination when sown may vary. In getting a satisfactory stand in the seed-bed not only the total germination but also the short interval within which this germination is attained, is an important consideration. There is evidently a great deal of varietal variation with regard to this characteristic. At Coimbatore, where every year a large number of varieties is sown at the same time, observations taken with regard to the rate of germination of the varieties in the seed-bed showed that while some varieties finished their germination in a couple of days, others dragged on for nearly a week. GEB. 24 was markedly slower in germination than others. Apart from other morphological differences, this variation has probably something to do with the thickness of the husk. The seed remaining dormant in the soil or germinating very slowly is a wild character and in several of the wild rices of our collections, the germination is found to be very slow and protracted. The seed of wild rices is found to remain dormant in the soil even for a year. The progenies of crosses between cultivated and wild types are found to exhibit this character in varying degrees suggesting that it is an inherited character.

Delayed and slow germination is characteristic of not only old seed but also fresh seed that has been stored defectively, exposed to wet weather. One way of overcoming this difficulty of delayed germination is to give the seed a longer soaking in water before sowing.

Influence of temperature.—The germination of rice is influenced by temperature, there being a wide range of optimum conditions. It germinates when subjected to a range in temperature from 42° F to 117° F or between 65° F and 71° F during the period of germination. Apart from varietal differences all rices germinate quicker at higher than at lower temperatures. There is very little germination beyond 108° F and the seeds are practically killed at 122° F. That temperature influences the rapidity of germination is evident from the fact that during the months of November-December when the atmospheric temperature is low in a greater part of the Province, the germination is always slower than when sown in July-August when the temperature is usually higher.

This temperature difference has probably a relation to the water-absorbing nature of the seed. Rice being a semi-aquatic crop, the grain absorbs water better under submerged conditions. Rice seed has a remarkable power of withstanding the action of water when steeped and this is probably due to the comparative insolubility of the nutrients in the seed. Though rice can germinate freely under water, germination is greatly retarded if the moisture in the soil where it is sown falls below 27 per cent.

Size of grain influencing germination and productivity.—Every seed sample contains seeds of varying sizes within the sample. For instance in a rice ear, the grains situated at the top and middle portions are always somewhat bigger and better filled than the rest. When the whole produce is harvested together it must necessarily contain grains of different sizes. If the axiom ' better seed results in better crop ' is literally true, the use of such heavy grain alone for seed purposes should result in better crops. It is this principle that is utilized in the practice of selecting grain for seed purposes by the salt-water method. Salt solution being heavier than water, the seeds that sink in it when immersed must be heavier and if such grain alone is used for seed purposes, the resulting crop gives more satisfactory yields. This has been put to the test in the case of rice with very definite results. For about four years from 1920 to 1924 at the Samalkota station, the seed sample was separated into heavy, medium and light seed in four varieties, *ratnachudi*, *palagummasari*, *garikasannavari and kanakasompu* and separately planted. There was practically no difference in the productivity of the three samples to justify the separation of the seed into heavy and light seed.

Recently at Coimbatore, the seed from strain Co. 4, a six months' crop, was separated into three classes, heavy, medium and light by actual weighments of individual grains and the three groups were grown separately. There was no difference in yield. Again the experiment was repeated with an early variety *kar* (3½ months) and it was found there was some advantage in the medium and heavy seed, the yield per plant being higher in these groups than in the light seed.

It is possible that in the early variety, the advantage of a better start obtained by the plant from a heavy seed continues for some time and since the period of maturity is short the advantage of the better start is seen. In the late variety, however, the initial differences level out later as the growing period is fairly long. This is parallel to the advantage gained by planting better grown seedlings in the case of short duration varieties whereas such advantage is not apparent in a late variety. This experiment has been conducted at a number of places in foreign countries and the general result of all such experiments has been that if the seed is from a pure line, i.e., seed developed from the produce of a single plant breeding pure for all its characters, there cannot be any inherent difference among the individual grains.

Natural loss of viability with age has been dealt with and loss due to want of drying and defective storage have also been mentioned. There is still another cause of deterioration of seed, due to the attack of insects during storage. The two chief insect pests attacking stored rice are the rice moth and the rice beetle of which the former is the more common one. The only feasible

remedy is to occasionally spread out the grain on a floor exposed to the bright sun and store it again after a thorough cleaning. Mud pots and mud bins may be made insect proof by a covering of cow-dung at the mouth. A good method consists of preserving the seed in a mud bin placed on a wooden frame. The top is sealed by a layer of fine dry sand and the seed is drawn off through a hole at the bottom.

In bad cases of attack by insects, the receptacles may be fumigated with some poison like carbon-bi-sulphide. For storing small quantities of seed in tins or small bags the addition of a few balls of naphthalene in the receptacle prevents the multiplication of the insect and the seed is kept viable for a long time satisfactorily. Experiments conducted at Coimbatore have shown that the addition of naphthalene does not in any way affect the viability of the seed under dry conditions.

CHAPTER XI

Manuring

(i) *Principles of manuring rice.*—Rice cultivation as practised in South India differs essentially from ordinary cultivation in (1) that the land is prepared for the crop by a system of puddling in water and (2) the land is kept flooded in a swampy condition during the greater part of the growing season. The puddling of the land previous to transplanting affects the physical condition of the soil and produces a finer and more clayey texture. This process should tend to make the soil heavier and heavier as years go on. Because of this, the first problem involved in the manuring of rice is the question of using manures which will tend to counteract this effect. Organic manures have a beneficial effect on the texture of the soil. That the addition of a bulky organic manure like green manure to rice soil is recognized as a beneficial practice meets this point.

The fact that the land is kept fully saturated with water throughout the greater part of the growing season means that there is practically no free oxygen present in the soil and this draws a sharp distinction between rice cultivation and that of ordinary field crops. In ordinary soils the nitrogen of the manure after going through many intermediate changes, unites with the oxygen of the air to form nitric acid, a substance which is easily absorbed by the crop. On the other hand in rice soils, no oxygen being present, instead of nitric acid, ammonia is produced, and it has been found in Japan several years ago that the rice plant readily assimilates this substance and consequently the products of the decomposition of many manures in such soils are suitable for the needs of the plant. Fermentation in rice soils being anærobic, nitrates are decomposed and the nitrogen is liberated as free gas. Since rice plant cannot make use of this nitrogen, nitrates need not be used for rice.

Rice is a cereal crop and requires besides nitrogen mentioned above, phosphoric acid and potash also. The soil contains all the plant food required but not all in a form capable of being utilized by the plant. Only portions that can dissolve in water known as ‘ available plant food ’ are useful to the crop, whereas the total plant food in the soil forms a reserve for the plant to draw upon. A rice crop giving 3,000 lb. of grain and an equal amount of straw from an acre removes from the soil roughly 48 lb. of nitrogen, 23 lb. of phosphoric acid and 41 lb. of potash. These will have to be replaced if the soil is not to be depleted of its fertility. But in Nature there is a mechanism for the indefinite supply of the bare minimum

requirements for what is known as the minimum crop production, i.e., the soil is able to replenish the loss sustained by the removal of the crop. This is exemplified in the fact that in certain soils over 2,000 lb. of rice are harvested every year without the application of any manure at all.

The comparative merits of the soil with regard to its manurial requirements can be judged only by chemically analysing the soil and estimating the total and available quantities of nitrogen, phosphoric acid and potash. Soil surveys of the important rice tracts of Madras have been made and these have yielded striking results showing in a marked manner the deficiencies in particular ingredients. The following table gives an idea of the nature and the extent of deficiency noted :—

Name of tract.	Percentage of soils deficient in	
	Nitrogen.	Phosphoric acid.
Godavari	40	23
Kistna	33	55
Guntur	80	33
Tanjore	87	80
Periyar	..	90
Malabar	..	90

With the aid of the data secured by the survey, it has been possible to ascertain the manurial needs of the areas and the nature of action of the manures was then taken up for investigation. The results of a large number of experiments in the field and in the pot house spread over a number of years have shown that all the natural and artificial nitrogenous manures are more or less beneficial to rice but they are most economical when applied in conjunction with bulky organic manures. Of the latter class of manures, green manures are particularly suitable to the rice crop.

Fermentation and function of green-manure.—The nature of the action of green manuring in rice soils was one of the earliest of the investigations undertaken by the Agricultural Chemist at Coimbatore. The investigation has been mainly in the nature of examining the gases evolved when the green manure decomposes in the soil. It was found that the gases escaping through and at the surface of the water in the rice fields were oxygen and nitrogen, while marsh gas, hydrogen and carbondioxide were found inside the soil. Further studies proved that the evolved oxygen was absorbed by the plant for its growth. Rice though it grows in water, does not have the roots characteristic of aquatic plants. The roots require plenty of æration and this is supplied by the

oxygen evolved. The evolution of the oxygen itself has been traced to a film of algæ commonly seen on the surface of the rice fields and this film was found to contain bacteria which oxidise hydrogen and marsh gas with the production of carbondioxide. The carbon of this gas is utilized by the algæ as their food liberating the oxygen which dissolves in the water and ærates the roots. This æration of the roots is possible only if the water with the oxygen dissolved in it could reach the root zone by drainage, so that drainage becomes an important factor. But experiments have shown that the æration of the roots is not so satisfactorily managed if the soil is too well drained. Simple draining would only let the roots have access to a weak solution of oxygen but where the percolation is slow the water is strongly charged with oxygen and therefore supplies plenty of it to the crop. A simple system of slow movement of water through the soil has been found to be most beneficial to the crop. The reason for this has been traced to the fact that the development of the film which is responsible for the supply of oxygen occurs best under moderate drainage conditions.

The presence of organic matter in green manure leads to increased fermentation going on in the soil and would lead to greater production of oxygen by the algal film. The research work has also shown that during the fermentation of the green-manure, the nitrogen escapes as free gas and has led to the conclusions that the nitrogen of these organic manures has little actual manurial value, that the crop is mainly dependent upon soil nitrogen for its support, and that green manures owe their efficiency mainly to their indirect action on the soil by increasing root æration. Nevertheless the green manuring of rice as practised in Madras has yielded exceedingly good results in the past and the use of these manures is rapidly extending.

The maximum benefit of the green manure can be got only when other soil factors are simultaneously improved. The most promising line of experiment would appear to be to find a suitable system of manuring which would employ green manures in conjunction with mineral manures. Generally speaking rice soils in South India are deficient in phosphorous and nitrogen and of these the former is easily made good by the use of bonemeal, superphosphate, etc. With regard to the latter, to produce improvement by the direct supply of nitrogen, the manure cannot be a bulky organic manure and it should be in a form assimilable by the crop. The only manures which answer these requirements are ammonium compounds and compounds of the type of cyanamide which yield ammonia on decomposition. Because they do not have any indirect effect of increasing root æration it would be desirable to use them in conjunction with green manures. Thus the whole principle amounts to the application of some of the phosphatic or nitrogenous fertilisers in conjunction with green manures to get the maximum effect.

The results of the manurial experiments can be expressed numerically in terms of the green manure, taking it as equal to 1.

No manure	0·33
Phosphatic manures alone	0·50
Nitrogenous manures alone	0·70
Nitrogen + Phosphate	0·90
Green manure	1·00
Green manure + P_2O_5	1·20
Green manure + N.	1·33
Green manure + N + P O_5	1·60

Nitrogenous and phosphatic manures are, in general, needed and there is response by the crop when they are applied singly or together but the combined effect appears to be better.

This raises the question of the proportion in which they have to be mixed. While this question is mainly one of cost, certain results obtained at Coimbatore, appear to indicate that the supply of N in the proportion of 2/5 artificials and 3/5 organic might be advantageous. Increase in the dressing of green leaves appears to make the action of artificial manures, particularly nitrogenous, ineffective.

Green manuring and green-leaf manuring.—When the action of green manures is only indirect, we have to consider the relative values of the two systems of green manuring commonly practised in South India, i.e., a comparison of the system of growing a green manure crop on the soil to which it is to be applied with that of manuring with green leaf or a green crop brought from outside. The green crop usually grown in rice soils is leguminous in character and obtains a proportion of its nitrogen from the atmosphere; but in soils already rich in nitrogen it is probable that the crop takes the nitrogen only from the soil. In the case of the non-leguminous crop all the nitrogen would be taken from the soil. When the nitrogen contained in it is dissipated as gas when the crop is ploughed into the soil, the crop ceases to have any direct manurial value. This should point out to the conclusion that the practice of growing a green manure on the soil itself for ploughing in, particularly a non-leguminous type, could not be as profitable as bringing leaf from outside and ploughing it in. The indirect action of the green manuring is also borne out by equally good results obtained by ploughing in a non-leguminous crop. That in addition to its indirect effect there may be a slight direct effect also is evident from the experiments in Ceylon where it is stated that large quantities of ammonia are made available to the soil at all stages of the decomposition process which coincides with the period of rice growth.

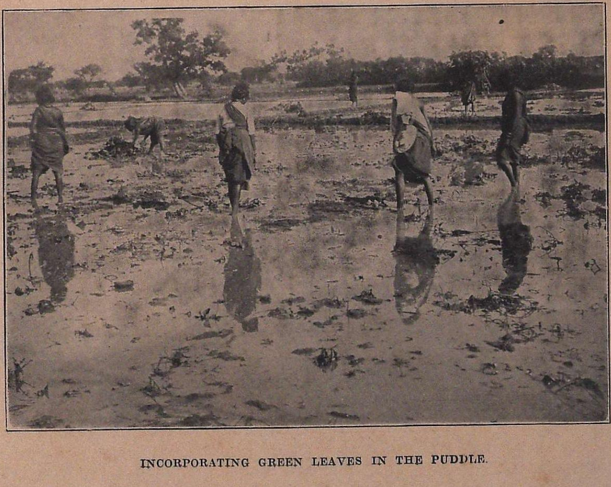
Green-leaf manuring.—The practice of green-leaf manuring generally obtains throughout the Province. Wherever forests are adjacent to the fields, green leaves are either brought or bought

in cart-loads and applied to the soil. The value of green-leaf manuring particularly for light and well drained soils has been recognized. In South Kanara, there is the peculiar practice of not applying the green leaves collected straight to the field. They are first put into the cattle stalls as a bedding for the animals and, after they get incorporated with the dung and urine of the animals, they are removed and applied to the fields. In bringing leaves from outside, practically any and every leaf available is used, the comparative value depending upon the rapidity of their decomposition in the soil. Leaves of leguminous shrubs and trees are however, usually preferred. *Kolinji* leaves (*Tephrosia purpurea*), leaves of *cassia* and leaves of *Pungam* tree (*Pongamia glabra*) are highly valued in several places. In Malabar any leaf obtainable from the forests or avenue trees close by, is used.

Green manuring practices.—The practice of actually growing a green manure crop in the fields, though it existed here and there before, is becoming universal, due chiefly to departmental activities. Collecting, stocking and selling of green manure seeds to the cultivators is still an important item of the departmental propaganda. The crops recommended are all leguminous. The success of raising a green manure crop in rice lands depends upon the type of land, whether it is single or double-crop land, the nature of the soil and the availability of water. The rice fields which are generally heavy clays and which carry a single crop in a year remain fallow in the hottest part of the year when deep cracks are formed and it is very difficult to cultivate the land and sow the green manure unless the fields are flooded. The adverse effect of dry ploughing in summer has already been touched upon. Evidently the dry ploughing and the subsequent puddling affect the physical condition and make the percolation of water (which has been found so necessary), more difficult. While the harmful effects of cultivating the soil in summer are not so apparent in loose and loamy soils, experiments at Maruteru and Aduturai have shown that even in the heavy soils, the harmful effects of summer cultivation are more than counteracted by ploughing in green manure. What the harmful effects of summer ploughing are really due to, and how green manuring counteracts them, are not properly understood.

Usually in the Godavari delta, the rice crop is off the land by November and the land has to remain fallow until next June. A crop of sunnhemp is usually grown under the rice before it is harvested and this is mostly cut and fed off to the cattle before March and there is very little left that goes in as green manure to the following rice crop. Since canal water is available till the end of April, it has been found practicable to cultivate the land and sow a green manure crop by the middle of March and plough it in in June. Over a great portion of the area even without any manure and elaborate cultivation, the first rice crop gives an acre yield of over 3,000 lb. grain and an equal amount or more

A CROP OF SUNNHEMP BEING PULLED OUT FOR APPLICATION TO RICE FIELDS.



INCORPORATING GREEN LEAVES IN THE PUDDLE.

of straw. Particularly in years when the summer has been rainless resulting in very deep cracking of the soil, even without any manure, the crop grows too rank and often has to be cut down once or twice to prevent lodging before the grain is formed. In such soils the value of green manuring becomes doubtful. Work has been directed to sow the green manure crop in the standing crop of rice and keep it on until June, cutting it down once or twice in the meanwhile and to use the cuttings for feeding cattle. This is, however, possible only with particular types of green manures.

Value of green manure.—The value of green manure is most apparent in soils of average fertility containing less than 0·07 per cent. of available nitrogen and less than 0·06 per cent. phosphoric acid. The increase in the produce obtained as a result of green manuring varies in different localities. While in soils above the average level of fertility it has been about eight to ten per cent., on poor soils and lands of average fertility the increase recorded has been to the extent of 20 to 25 per cent. even with an application of three to four thousand pounds of leaf per acre. The good effects of green manuring have been particularly striking during bad seasons. The rise of the average acre yield of rice in Coimbatore wet lands from 2,000 lb. to nearly 4,000 lb. has all been due to the systematic growing of a green manure crop in rotation with rice. In Hospet area of Bellary district, rice is alternated with sugarcane (two years' rotation) and in spite of the fact that cane is an exhausting crop, the average yield of rice has always been above 3,000 lb. per acre, due to the practice of growing a crop of sunnhemp as green manure between the rice and the sugarcane.

The amount of leaf to be applied varies very much. From the several experiments that have been conducted, it may be said that four to five thousand pounds of leaf per acre will be an optimum dose for rice. In some places even larger doses than four to six thousand pounds have given significant increases in the yield of rice. Where the doses have been increased to six to eight thousand pounds per acre in some poor soils, repeated applications of such heavy doses have been found to depress the yield unless supplemented by some form of phosphatic manures such as bonemeal and super-phosphate.

The several green manure crops grown in Madras are dealt with separately. It has not been possible to make any systematic comparison as some of them thrive only under particular conditions. Problems like their comparative efficiency as nitrogen fixers, relative rate of decomposition in the soil, etc., have not been investigated. Under average conditions, the choice can always be between sunnhemp and *pillipesara*, while daincha may be suitable for heavy and slightly saline soils and wild indigo for rather poor, gritty and loamy soils. For Malabar soils, however, nothing has done so satisfactorily as cow-pea for green manuring. Indigo when it was being grown extensively in South Arcot and

Vizagapatam districts for the production of the natural dye, the waste called the *seeth* was freely used as manure and was highly valued. Since it is not grown so extensively now, its use as a green manure crop alone, is confined to certain specially favoured situations.

The quantity of green matter obtained from an acre of crop varies with the conditions, and normally a yield of 8,000 to 10,000 lb. per acre may be expected. But under favourable conditions as at Coimbatore and Maruter, *pillipesara* and sunnhemp have given phenomenal yields of 20,000 to 30,000 lb. of green matter per acre. Under such conditions the quantity obtained from an acre of crop should easily suffice for fertilizing five to six acres. Daincha can also, under favourable circumstances, give fifteen to twenty thousand pounds of green matter but the main trouble with regard to this is that the stems get woody and the question of cutting and incorporating them into the soil becomes a difficult proposition. The comparative merits of the green manure crops will, besides the total quantity of green matter produced, depend upon the ease with which the plants can be cut and applied to the fields. Even with daincha which generally grows woody by sowing it late and thick, handling might be made easier.

Cost of green manuring.—The cost of growing a green manure crop is comparatively low and it has been found to be the most economical method of fertilizing rice fields. From the figures available in the different experimental stations, the cost of growing an acre of green manure crop varies within wide limits, from Rs. 7 to as much as Rs. 30 per acre, the higher figure being associated with cases where irrigations were given and the yield of green matter was above 25,000 lb. The average cost varies from seven annas to one rupee per thousand pounds of green matter and thus an application of 4,000 lb. of leaf per acre should not cost more than Rs. 4, and it is not possible to think of any fertilizer which can give comparable results with 4,000 lb. of leaf for the same investment. It is not uncommon among cultivators to pay as much as Rs. 3 to Rs. 5 per thousand pounds of green leaf brought from outside. Though the beneficial action of green manuring was stated to be not due to the nitrogen contained in it, its action is very similar to that of a nitrogenous manure and has given results comparable with a chemical fertilizer like ammonium sulphate. Comparing the value of nitrogen per pound in a fertilizer like ammonium sulphate and nitrogen in the leaf, the cost of nitrogen in the latter is only a fraction, one-sixth to one-eighth, of that in the fertilizer.

(ii) *Green manure crops.*—Of the several green manure crops here described, the choice of any depends upon the local conditions of soil, season and climate. Besides what are mentioned here many of the pulse crops like blackgram, greengram,

horsegram, cowgram, are also used for the purpose. The cultivator himself knows which of the several pulses will grow and under what conditions in his wet lands. While discussing about rotations, the various pulses grown in the different parts of the Province in rice fields were mentioned. Though they may be grown mainly for the grain, they may be used for green manuring also; when some grain is obtained the aftermath is invariably ploughed in as a green manure.

Sunnhemp (*Crotalaria juncea*).—This is perhaps grown more largely than any other green manure crop. It is grown practically all over the Province except in Malabar. Every year large areas are grown in Kistna and Godavari deltas. The seed is sown just before the rice is harvested and the crop is cut when it is about four to eight feet high. The tops dried make excellent fodder. Because of its rapid growth, it is the crop to grow where only short intervals are available between two rice crops. It is, however, a sensitive crop and cannot stand very dry conditions. It is also very sensitive to water-logging. Its use is confined to well-drained lands where irrigation can be given if necessary. With irrigation it can give a heavy crop within six or seven weeks. In Coimbatore, sown in ploughed fields in April-May with one or two irrigations it has given in a two months' period heavy crops of twenty to thirty thousand pounds of leaf per acre. Because the stem is fibrous it decomposes very readily when ploughed in.

It is often subject to the attack of caterpillar and flea beetle pests and if the attack comes in at an early stage, the crop may completely fail. Since it is a fodder crop readily eaten by cattle, it cannot be grown where cattle trespass cannot be prevented. There are varieties varying slightly in duration and the required variety can be grown. The seed-rate for the crop is fifteen to twenty pounds per acre.

Wild indigo or kolinji (*Tephrosia purpurea*).—This is considered to be the most valuable crop because of its hardiness and drought resistance. Sometimes cultivators travel several miles to cart it from waste lands to their rice fields. It thrives best where the soil is loamy or a bit gritty and not too heavy. It will not stand any water-logging. For sowing in standing rice crop in single-crop lands where the land remains fallow for nearly six months, it is the ideal crop to grow. It requires moisture only for germination and it can thrive later without any irrigation or rain. It is rather slow growing in the beginning but if there are any summer showers, it bursts out well and gives a good crop of green matter. It can be sown mixed with some more rapidly growing pulse crops. The plant usually forms some seed before it is cut. The seed, because of its hard coat, can remain dormant in the soil and so, when once a good crop is established, there will probably be no necessity to sow it again, unless heavy hot weather showers kill it outright. Cattle do not eat it and therefore it can be grown in open fields.

The seed of *kolinji* does not readily germinate and it takes some years before a good crop of *kolinji* can be established. The seed is usually dressed before sowing, i.e., it is pounded with sand so that the seed coat is damaged to facilitate absorption of moisture. Though the crop does not give as large quantities of green matter as the sunnhemp, it is specially chosen for its hardiness. About three to four thousand pounds per acre will be a good yield for wild indigo.

This is grown principally in the Tamil districts of Tinnevelly, Ramnad, Madura, Trichinoply, Tanjore and South Arcot, but it can also be seen in Kistna, Nellore and Guntur districts. The seed-rate used is ten to fifteen pounds per acre.

Daincha (*Sesbania aculeata*).—This is a valuable green manure crop on heavy soils and especially on lands inclined to be saline. It has been found useful to reclaim saline lands in the coastal regions of Godavari and Kistna where other green manures will not grow. It is a drought resistant plant and at the same time can withstand wet conditions. Its spread as a green manure crop is due to the departmental propaganda. The greatest success with this crop has been on tank-fed lands which are supplemented by wells as in Chingleput, South Arcot, etc., districts. It can be sown either pure or mixed with a cereal such as *cumbu*. As a pure crop it is usually grown in May-June and after three months, is ploughed in for the *samba* crop coming in July-August. It can also be used for sowing in single-crop lands just before the harvest of the rice crop. Under these conditions, unless it is sown very thick, the stems get woody and there will be difficulty in incorporating them into the soil. A successful method of dealing with the crop under these circumstances is to cut the crop a little early and compost it in pits for about two months and then use it in the fields. Even in single-crop lands the crop can be sown after ploughing the lands in April-May and then irrigated. In this case it will have to be sown thick to give a good tonnage of green matter. Since it may be ploughed in within three months, the stems will be succulent. Though under favourable circumstances when sown late and thick, even twenty thousand pounds of green matter per acre may be obtained, eight to ten thousand pounds can ordinarily be expected under any circumstances.

This has spread to several parts of the Presidency, Vizagapatam, Godavari, Kistna, Chingleput, Salem, Coimbatore and Madura (Periyar area) districts.

The ordinary seed-rate is eight to ten pounds per acre, if it has to be grown mixed on single-crop lands and allowed to remain for nearly six months. For late sowings the seed-rate may be raised to twenty pounds.

Indigo (*Indigofera tinctoria*).—This is also a hardy plant and is useful for sowing in single-crop lands in the standing crop of rice, just before harvest in December-January. Like wild indigo it is

slow-growing in the beginning but bushes well later, if there are any summer showers. It thrives best in loams and clay loams. Because of its long duration, it could be sown mixed with some other rapidly growing pulse like green or blackgram. After the pulse is harvested the indigo remains in the field until next June. It is drought resistant and has a deep root system. If the hot weather rains are favourable, this crop may be cut back and allowed to grow again. The cuttings can be used for manuring seed-beds which have to be raised early. In some places under tank irrigation where the water-supply is supplemented by wells, and a dry cereal crop, usually *cumbu*, is grown with the aid of the well water, indigo is sown mixed with *cumbu*. After the *cumbu* is harvested, the indigo is left alone and gives a luxuriant crop before the *samba* rice season commences. In Vizagapatam it is also grown mixed with gingelly. Indigo is getting popular in parts of Tanjore district.

The seed-rate is the same as for wild indigo and the seed being hard it may have to be treated before sowing. Under favourable conditions it can give about eight to ten thousand pounds of green matter per acre.

Pillipesara (*Phaseolus trilobus*).—This is a new green manure crop introduced from Kistna some ten years ago and is now rapidly expanding to all parts of the Province. The seed is edible. It gives a good green forage and is an ideal green manure crop, quick to grow and easy to be ploughed in. It can be sown in all seasons and seed production is abundant. In Godavari it is advantageous to grow it mixed with sunnhemp both in single and double-crop lands. In the second-crop lands after the sunnhemp is cut for hay, the *pillipesara* can be ploughed in for the second crop. In the single-crop lands after the harvest of sunnhemp it gives good grazing for the cattle in March. The stubble flushes again with an irrigation and gives plenty of green matter for ploughing in, for the first crop of rice in June.

It has been tried in other places also in single-crop lands. It can be sown in the standing rice crop before harvest and if the weather is favourable it can be cut once for fodder and the aftermath ploughed in for the rice crop. It has possibilities as a combined green manure and fodder crop in Tanjore and Coimbatore. If the soil does not dry out too quickly or if an irrigation could be given in summer, very heavy yields of the crop can be obtained. Under favourable circumstances it can give fifteen to twenty thousand pounds of succulent and easily decomposing green matter. It has proved a success even when it was sown in a ploughed field after the harvest of the rice crop in February-March provided an irrigation could be given to start the crop. At Maruter it has given more green matter than sunnhemp or daincha sown at the same time. There is a great future for this crop, and in the trials and in popularizing it, the Maruter station has taken a leading part.

For green manuring purposes a heavy seed-rate of thirty to forty pounds of seed per acre is advisable.

Other crops.—Besides the green manure crops mentioned above, the cow-pea is one extensively used in Malabar. It is found to do better than other green manure crops for the Malabar conditions. It is grown both in the single and the double-crop lands after ploughing the land first. Under favourable conditions eight to ten thousand pounds of green matter may be expected and being succulent it easily decomposes in the soil.

Provision of green manure seed.—In Kistna and Godavari where sunnhemp is regularly grown for fodder purposes, there is always scarcity for seed and it has to be obtained from the high lands. The seed is often expensive. Even for the daincha and indigo seeds, high prices have often to be paid. It is possible, however, for the cultivator to provide himself with his own seed by taking a little care to sow some seeds on the field bunds and allow the plants to seed. Utilizing the field bunds for some odd crop or another, is a practice obtaining in the Godavari delta and parts of Malabar and could well be copied in the south, particularly in Tanjore.

The successful raising of a green manure crop rests almost entirely with the cultivator. For Tanjore soils besides wild indigo, and indigo which might be sown in the standing rice crop in January and allowed to grow on until next June for single-crop lands, it has been found possible to grow a green manure crop even after the receipt of the freshes in rivers in June-July. If the land is ploughed in summer with the help of showers and some green manure seed sown and irrigated as soon as water is available in the channels, in middle of June, a fair crop can be obtained by August when the land has to be prepared for planting. For such trials sunnhemp and daincha are found quite satisfactory. They can give an yield of eight to ten thousand pounds of green matter per acre.

(iii) *Other bulky organic manures—Cattle manure.*—With the knowledge that bulky organic manures are beneficial to the rice crop, other indigenous bulky manures may now be considered. The foremost among them is cattle manure which is the only one universally available and applied to the crop. There is no doubt that it is about the best, but the main difficulty is with regard to the inadequacy of the supply. In the Tanjore delta where it is the only source of manure supply, the quantity available is hardly sufficient for about one-tenth of the whole area. Because of the absence of forests nearby, and the difficulties about obtaining fuel for household purposes, a considerable quantity of the cattle dung is used away as fuel. The available quantity is all used for the seed-beds and to the first crop in the second-crop area, the main single-crop lands going practically without any manure. There is no doubt that here, much of the area has been reduced to the natural minimum fertility level. The cattle manure available in the country is a very poor stuff due to the very bad ways adopted in making and preserving it. The care bestowed in South Kanara to prepare cattle manure, mentioned already, is unique in this respect. Propaganda about better methods of preparing and storing the

manure has always formed one of the important activities of the department. The several methods of preparing cattle manure, the heap, the loose box, and the pit have been experimented with in several of the agricultural stations and the comparative merits of the manure prepared in different ways tested by application to rice crops.

Instead of collecting the manure and spreading it on the field, penning of cattle and sheep straight on the fields is a common practice. Sheep penning is common throughout the Province except probably in Malabar, and cattle penning is practised in Vizagapatam, Kistna, Ganjam, Madura and Tinnevelly districts.

Composts.—With the scanty supply of cattle-manure available, and with the recognition of the importance of organic matter to the soils, greater attention has been paid in recent years to convert all vegetable wastes into manure by composting them. There are several methods of which the Indore method appears to be the most suitable for composting all farm waste. It can be even modified and simplified according to local requirements. In Madras, what is known as the pit method of composting is adopted and appears to be quite simple and satisfactory.

Ordinary *municipal rubbish* forms an excellent bulky organic manure for rice fields. Unlike in the case of other crops, the material need not be composted first, but applied straight to the fields and the fermentation allowed to take place after the field has been puddled. Application of large quantities of municipal rubbish in some of the Periyar rice areas of the Madura district, particularly in soils tending to become alkaline, has given satisfactory results.

Night-soil.—This is also a useful manure for rice fields but has to be converted into poudrette by composting, to facilitate handling. The objection to the use of this manure appears to be only sentimental. Good results have been obtained by its application, at Government stations. In fact, it is one of the most common things used for fertilizing rice fields in Japan where high acre yields are recorded.

Among bulky organic manures may be included the different oil-seed cakes available in the country and fish manure. They can be utilized with advantage, the only limiting factors being the availability and cost at any particular locality. They contain a much larger proportion of nitrogen, and other mineral ingredients than green manures and consequently can be used in much less quantity. They are complete manures and there is generally little necessity to use any other manure in conjunction with them. Bone meal is also included among the bulky organic manures. It is exceedingly rich in phosphoric acid and contains a fair amount of nitrogen and undergoing rapid decomposition in rice soils makes the manurial ingredients available as plant food. It is, however, best used in conjunction with green manure, as the decomposition of the green manure assists to dissolve the phosphoric acid of

the bones and thus makes it much more available to the plant than it would otherwise be.

In some places as in Kistna the rice straw itself is applied in large quantities to the rice fields as manure. It is considered particularly useful for reclaiming alkaline lands. Since suitable green manure crops like daincha can be grown on such lands, the efficacy of straw application is doubtful.

In parts of the Province as in Kistna delta, the value of '*patti-mannu*,' old village site earth, is valued highly as a manure for rice fields. All the available quantity of this has probably been already used up.

(iv) *Mineral or artificial manures—Phosphatic manures.*—The manures of this class to be considered in connexion with rice crops are very few. The most important phosphatic manure is superphosphate, either mineral superphosphate or bone superphosphate according to what it is prepared from. It is easily soluble and becomes readily available to the plant when applied to rice soil. There is also a certain amount of flour phosphate prepared by crushing minerals containing a large amount of phosphoric acid in an insoluble form. There are large deposits of phosphatic nodules in Trichinopoly district and the use of the flour prepared out of it as a manure for rice soils has been the subject of experimentation at a number of places. There are also sometimes available on the market other phosphates like Kossier phosphate, in which also the phosphoric acid is present mostly in an insoluble form.

Nitrogenous manures.—Among the nitrogenous manures, the most important is ammonium sulphate. It is a quick acting manure, quite suited to rice and its use was generally coming into practice in spite of its high price until recently, before the price of rice went down. Other nitrogenous manures that might be considered are the calcium cyanamide and sodium nitrate. Calcium cyanamide releases ammonia which is the form in which the rice plant takes in nitrogen, and was considered a useful manure and it has been the subject of experiments. Sodium nitrate is not of importance to rice crop though it has also been experimented with at the agricultural stations. Certain physiological experiments conducted recently with rice in Bombay would appear to point out that the plant can take nitrogen both in ammonical and nitrate forms, and the absorption is more in the ammonical form in the early stages which gradually decreases while the absorption in the nitrate form increases as the plant gets older. This observation has led to the suggestion that a mixture of nitrate and ammonium sulphate should prove a better source of nitrogen to the plant than ammonium sulphate alone. This, however, has yet to be confirmed by field experiments.

Compound manures.—Recently there are available on the market compound mineral manures containing in a concentrated form both nitrogen and phosphoric acid. There are a number of them, named ammophos, leunophos, and niciphos and except that they are

different patent names adopted for trade purposes by different manufacturers, their manurial values are about the same. There are, however, two grades of them one in which the nitrogen and phosphoric acid are present in equal proportions and the other in which the phosporic acid is present to a larger extent, about two to three times that of nitrogen. These are also slowly coming into use, and should be considered cheap for their manurial contents but their extensive use is limited by the prevailing low price for rice. These are being recommended for use for the rice crop in Burma, the United Provinces, the Central Provinces, etc., as they are considered particularly useful for fertilising seed-beds.

All the mineral manures do not fulfil the necessary condition of supplying organic matter to the soil and best results are generally obtained only when they are used in conjunction with bulky organic manures. There may, however, be exceptions where the application of any one of these by itself gives a satisfactory return, when it is known that the soil to which it is applied, has been found to be particularly deficient in any one manurial requirement. Such responses are likely to be only temporary and to maintain enhanced rate of cropping the best course would appear to be to use the mineral manures in conjunction with organic manures.

(v) *Results of manurial experiments.*—Manurial experiments have been carried on at all the agricultural stations. The results could either be discussed according to the manures or according to the stations. Since the stations are situated in the important rice tracts and as the results are applicable to the individual tracts the latter method has been adopted. The results of manurial experiments in Madras were compiled by a Special Officer on behalf of the Imperial Council of Agricultural Research and this compilation has been made use of, supplemented by information that has become available since then.

Anakapalle.—The soil of this station is a red loam, representing the most common type of soil in Vizagapatam district. The farm soils are sufficiently rich in phosphoric acid (available $P_2O_5 = \cdot 03$ to $\cdot 05$ per cent.) and probably do not require any phosphatic manuring. Trial of super. does not give any sufficient response but green leaf manuring with sunnhemp or wild indigo (2,000 to 3,000 lb. of leaf per acre) gives an average increase of 10 per cent. grain and 15 per cent. straw on mean yields of 2,300 and 3,200 lb., respectively.

Maruter.—This represents one of the most fertile rice areas of the Province and the first *sarva* crop easily yields 3,000 lb. of grain an acre. The value of nitrogen and phosphoric acid on such lands, and the best stage of the crop at which the nitrogen could be applied has been tried. The increase obtained is neither marked nor consistent. Application of nitrogen one month after planting gives the best results.

The subsidized manurial trials in co-operation with the different manure firms has been carried on for five years in a specially selected leased area. The various chemical manures like leunophos,

ammophos, sulpuro phosphate, etc., do not give any consistent results. The average increase for all years is about eight to ten per cent. only on a basal dressing of 4,000 lb. of leaf. The response to manure is poor in the first crop but very much better in the second crop resembling Samalkota results. The salient features of these trials are: (1) green leaf definitely increases the yield; (2) organic manures like cakes serve the same purpose as green leaf; (3) fertilizers like ammonium sulphate, ammophos, niciphos, etc., are as good as green leaves in increasing the yield; (4) the above fertilizers when applied in conjunction with leaves give increases over plots receiving leaf only; (5) phosphatic manures give no response over the application of green leaf; (6) the increases of yield are generally in the nature of 10 to 15 per cent. only; and (7) it will not be an economic proposition to resort to any of the artificial fertilizers with the present low price of rice.

The excellent value of *pillipesara* for green manuring purposes is very evident at this station. It has also been shown as a result of experiments at this station that facilities exist for growing green manure crops for both crops of rice.

Samalkota.—This represents the heavy deltaic soils of Godavari occurring in a great portion of the Eastern delta. A large number of manurial experiments has been carried on here from the very beginning. The farm soils contain from ·05 to ·09 per cent. of nitrogen, ·01 to ·02 per cent. of available potash and ·002 to ·015 per cent. of available phosphoric acid. The range in respect of N and P_2O_5 is wide and covers plant requirements from slight deficiency to moderate fertility.

A large number of manurial experiments has been conducted over a series of years with green manuring, ammonium sulphate, super, bone meal, fish guano, castor cake, potash, etc., both by themselves and in combinations. Experiments have also been carried out with big applications of rice straw (ten tons per acre) and with cattle-manure preserved in different ways.

The general conclusions of the various experiments may be summarized as below. Land beyond a certain fertility which can be indicated by an average yield of about 3,000 lb. of grain and with ·008 per cent. available P_2O_5 and ·07 per cent. N does not usually respond to manuring. Potash is well-supplied in all cases and its application either has no effect or is sometimes depressing, especially with ammonium sulphate. Phosphatic manuring is of first importance in the tract, and along with cakes increases the yield sometimes up to even 80 per cent. for the second crop in the double crop area. Green manures alone act beneficially in poor soils only. A mixture of green leaf and bone meal (or better super) is the best of all the manures. Next comes fish guano. Both have residual effects in the succeeding year, the former sometimes longer. Cyanamide has shown itself useful only in stray cases and has no residual value. Ammonium sulphate has acted beneficially giving even 20 per cent. increase, but its application is not necessary on green manured

lands. Castor cake has a slight direct effect; on the other hand it has a pronounced depressing residual effect which can be seen even in the fifth year after application. Rice straw is of no value on manured lands. Cattle manure preserved in the loose box is better than other cattle-manures and has also residual effect in the next year, but its use is limited due to the submerged condition of the tract.

Palur.—This is in South Arcot and represents a great portion of South Arcot district. The soil is a sandy loam with good drainage. It contains ·002 to ·05 per cent. nitrogen; ·003 to ·015 per cent. available potash; and ·006 to ·009 per cent. available phosphoric acid. Only nitrogen is in slight defect.

The effect of artificials is not material in soils represented by Palur and they do not supplement green leaf in any manner. The effect of green leaf is not cumulative when applied over a number of years, as it has not produced increased rates of yield but the remarkably increased yield produced in the first few years on poor land cannot be ignored. The inference is probably that green manures are capable of bringing up the yields on poor land in the first few years only after application and that afterwards they are not of much value in increasing the yield but are necessary in maintaining the fertility.

Manganallur.—This was a temporary station on the Eastern delta of Tanjore and was closed down after ten years' existence. Green leaf alone gives the best results, a 20 per cent. increase. It is best applied by puddling green. To avoid damage to texture of the soil, green manure sowing should be done in the standing crop of rice. Phosphate is found very essential. Even super. alone is able to give a 22 per cent. increase in yield. The slow acting phosphates are distinctly poorer than super. for either direct or residual effects. Ammonium sulphate has the same value as green manure but calcium cyanamide was definitely inferior. Ammonium sulphate has sometimes supplemented green leaf and sometimes not. Super acted beneficially in combination with green leaf or ammonium sulphate and to a less extent with cyanamide. Oil-cakes are by themselves good, increasing the yield up to 30 per cent. In combination they have the further advantage of making even slow acting phosphates, such as mineral phosphates or bone meal more available (40 to 80 per cent. increase). Potash has little or sometimes even depressing effect and inhibits the beneficial residual effects of super. Cattle-manure gives about 20 per cent. increase in yield.

The manures respond better in single crop lands than in the double. In the latter case application before the first crop *kuruvai* gives better results. Poor lands respond very well, while fields with a high cropping power sometimes show bad residual effect on account of manuring. As a general deficiency of both phosphates and nitrogen is indicated, a combination of these manures is best for the tract.

Aduturai.—This represents a great portion of the Cauvery delta. The soils of Tanjore delta contain ten times as much total potash (·2 to ·8) as phosphoric acid (·02 to ·08). Except some portions near Coleroon and in isolated areas of West Mayavaram most soils contain less than ·01 per cent. available $P_2 O_5$ and are very deficient in this. Potash is very well-supplied. Nitrogen is generally in defect (·04 to ·06 per cent. rarely). One of the marked defects of this area, and one likely to interfere with the results of manuring is inefficient drainage. This is more or less a general drawback and some lands are tending to alkalinity on this account. Any improvement in the tract could therefore be directed towards this end first.

So far as manuring at Aduturai is concerned, green leaf to supply 50 lb. N is economically the best. Sodium nitrate although it has increased the yield in some cases is not a paying proposition. Cattle-manure is beneficial generally. Loose box manure is very good on poor lands, but its superiority to other forms of manure is not well-established. Village cattle-manure is slightly inferior. Supplementing the same by sodium nitrate, ammonium sulphate or groundnut cake has not proved useful in all cases.

Coimbatore.—To find out a substitute for *patti-mannu* extensively used in Kistna, various combinations of nitrogenous, phosphatic and potassic fertilizers have been tried for rice. A mixture of one hundredweight of potash and two hundredweights of super. on a basal dressing of three to four thousand pounds of leaf give the best results, a 21 per cent. increase over 3,114 lb. for unmanured plot. The mineral manures by themselves give a poor response. There is an indication of the necessity for bulky organic manures.

Among the natural manures tried—black and white castor cake, fish manure, poudrette and bone meal—fish manure is the best giving a 35 per cent. increase over unmanured plot with 2,344 lb. Poudrette is beneficial and cake gives an increase of 18 to 20 per cent. while bone meal gives only a 13 per cent. increase.

The new manures ammophos and leunophos show that they are able to supplement cattle-manure. The ammophos of higher phosphate content does better and is equal to either ammonium sulphate with super. or cattle-manure with super. on an equal N and $P_2 O_5$ basis.

The potassic manures are found generally to depress the yields.

Sodium nitrate has been tried in conjunction with either green leaf or cattle-manure. Green manure alone and in combination with sodium nitrate gives the best results. Next come the cattle-manure combinations. Sodium nitrate by itself is no better than no manure.

Ammonium sulphate by itself or in combination with super. gives a significant increase in the first year, but the yields of subsequent years are very depressed.

Calcium cyanamide though it gives an increase is not economical.

Nandyal.—Experiments were conducted on leased wet lands irrigated by Nandyal tank at Tekkai from 1918. The practice of manuring adopted locally was to apply green leaves at about 4,000 lb. per acre and cattle-manure at about 3,000 lb. per acre. The objects of the experiments were (1) to compare green manuring and cattle-manuring with a view to introduce the former, (2) to understand the significance of the cattle-manure adopted in the local system and (3) to evolve a new scheme of manuring by which the bulky manure, cattle-manure and leaf could be either wholly or partially replaced by more concentrated manures.

The conclusions from the experiments are: (1) that ploughing in of a green manure crop wherever possible is almost as efficient as green leaf but inferior to local manuring, (2) that groundnut cake at 320 lb. and bone meal or super. at 100 lb. per acre give the same results as the local manuring.

Sirvel.—This station in Kurnool was closed down after some years. Experiments with rice manuring have given the following results. On unmanured lands and green manured lands super. is very beneficial. Bone meal also supplements green manure as efficiently as super. (20 per cent. increase). Green leaf manure is slightly inferior to green manure (wild indigo). Amongst green manures, *tangedu* (*Cassia auriculata*) is bad while daincha and wild indigo are of equal value. Groundnut cake supplements super. best.

Berhampur.—This represents the extensive rice area of Ganjam district. The soils are found to contain ·04 per cent. N, ·02 per cent. available P_2O_5 and ·02 per cent. of K_2O.

The station has been in existence for only five years and the indications of manurial trials conducted are given below.

Green manuring is found to be definitely beneficial. With regard to the dose, there is a progressive increase in yield of grain as the dose is increased from two thousand to six thousand pounds. With regard to the trial of fertilizers, an addition of 100 lb. of ammophos over a basal dressing of 4,000 lb. of green leaf gives a significant yield increase but the value of the increase does not cover the cost of the manure. Ammonium sulphate to supply 20 lb. of N over a basal dressing of leaves gives a definite yield increase but any further increase in the quantity of ammonium sulphate does not improve the yield. While super. either by itself or in combination with ammonium sulphate over a basal dressing of green leaves gives satisfactory yield increases, bone meal is not so effective. The application of lime does not seem to have much effect.

Pattambi.—The station is representative of a great portion of the Malabar Coast. Soils are all of laterite origin and are generally

shallow and poor. While even here the advantage of green manuring has been established, the main difficulty is the unsuitability of the natural conditions to raise a green manure crop. Wherever green manure crops of daincha, cow-pea and horsegram can be raised, they have proved advantageous for the double crop area.

Recent experiments with phosphatic manures do not show any response. Liming of the soil does not produce any results. A small dose of ammonium sulphate over a basal dressing of green leaves is of some advantage.

General.—Green leaf or green manure has been generally found to be beneficial in the entire rice area of the Province. Nitrogenous artificials, either alone or as supplements to green leaf are found useful in only limited areas with pronounced deficiency of nitrogen as at Manganallur and to a less extent as in Coimbatore, but there are harmful after-effects. Phosphates are very useful at Manganallur and Samalkota, super. being preferable to the slow acting phosphates. It is always best to apply phosphates in combination with other manures, as they have generally no value alone, except at Manganallur. A combination of green leaf, and bone meal or super. is found to do uniformly well wherever phosphate deficiency is indicated. At Anakapalle and Palur, phosphates are not found useful.

(vi) *Miscellaneous experiments*—(1) *Application of sand.*—When no response was obtained by manuring fields at Samalkota which are already known to be of a certain standard of fertility, it was considered that altering the physical condition of the soil might improve the response of the soils to fertilizers. An interesting experiment was therefore commenced by applying 400 cart-loads of sand per acre. The application of sand had an immediate harmful effect in that the yield was depressed. The depression gradually got less and less until after three or four years there was gradually no difference between sanded and unsanded plots. Experiments are now in progress to see if the fertilizers will give a better response in the sanded plots.

(2) *Kossier phosphate.*—A new phosphate like Kossier Phosphate which contains a larger amount of $P_2 O_5$ than bone meal and is slightly cheaper was tried as a fertilizer for rice at a number of places, Anakapalle, Palur, Aduturai, Coimbatore and Pattambi and in none of the places did it give a response and prove better than bone meal.

(3) *Compound manures.*—The compound manure, niciphos, has been tried for some years against a mixture of super and ammonium sulphate to give the same amount of N and $P_2 O_5$ and there has been no difference, although experiments in Burma have generally proved the superiority of these compound manures. It is the comparison of cost that should decide whether this is to be preferred to ammonium sulphate and super.

(4) *Dry and wet fermentation.*—Since the nitrogen of the green leaf applied to the soil has been found to escape as free gas, to see whether this escape could be prevented by altering the nature of fermentation, in certain fields of the Paddy Breeding Station, Coimbatore, in half the area green leaf was applied in the dry and ploughed in soon after the harvest of the rice crop in January and in the other half, the green leaf was applied after puddling the land in next June. Even the dry ploughed plot was puddled later and the crop transplanted. Comparisons of the yield showed that applying green leaf in the puddle was preferable.

In an experiment at Maruteru, application of sunnhemp hay as green manure was found to be as good as normal manuring, i.e., when sunnhemp is applied in a green state.

(5) *Manuring of seed-bed.*—In the case of transplanted crop, manuring of the crop is done at two stages one in the nursery, and the other in the transplant field. When the manure available is limited it would be useful to know where the manure could be more advantageously used, either in the seed-bed or in the field. It is sometimes believed that if the seed-bed is heavily manured and the seedlings are very vigorous, such seedlings when planted give a better crop and this would be one of the ways of avoiding the necessity to manure the transplant field. To test this point, experiments were laid out in Coimbatore with three varieties of rice of four, five and six months' duration, respectively. The seed-beds were prepared in three ways, (1) without any manure, (2) the ordinary method of manuring and (3) very intensively manured. The seedlings from the three types of seed-beds were each planted out in manured and unmanured fields. The development of the plants was studied as they grew and the final yields were recorded. It was found that in all the cases the manuring of the seed-bed had no effect and the manured transplant field, irrespective of the treatment of the seed-bed, gave a higher yield than the unmanured.

The intensive manuring of the seed-bed consisted of the application of 20,000 lb. of leaf besides one hundredweight of super. and one hundredweight of ammonium sulphate. The seedlings were naturally very much in advance of the others but in spite of their growth they were planted only on the same day. But taking into consideration only the growth of the crop, the seedlings of the intensively manured beds could have been planted about ten to fourteen days before the others, and if this had been done, we should not be able to decide whether the advantage, if any, was due to early planting or to the manurial treatment. Later modification of the experiment by planting the crop early, when the intensively manured seedlings were ready, has not shown any change in the trend of results.

A similar experiment has been in progress for two or three seasons in all the rice stations, Berhampore, Maruteru, Aduturai and Pattambi and in every case the intensively manured seedlings did

not prove superior. There were, no doubt, great differences in the seedlings when planted, but they all levelled out nicely in the end. The method of intensively manuring the seed-bed should prove particularly advantageous in forcing the seedlings in years when the season happens to be late.

The plant practically starts a new life after transplanting and the growth depends entirely on the fertility of the land. It therefore looks advantageous to give the available manure to the transplant field rather than to the seed-bed. This does not mean that the seed-beds need not be manured at all. Provided the seed-bed is moderately fertile, any available manure could be better used in the field than in making the seed-bed extremely fertile. The results of this experiment are significant in that they are similar in half a dozen places where the conditions are very different.

(6) *Time of application of manure.*—The bulky organic manures have to ferment in the soil and hence should be applied early enough. In the case of a quick acting fertilizer, however, the time of its application may have a relation to the plant development. A careful study of the development of the rice plant has been made in relation to applying fertilizers like ammonium sulphate. An experiment was conducted in Coimbatore, Pattambi, Aduturai and Maruteru, with ammonium sulphate as a fertilizer, varying both the quantity applied and the time of application. The experiment has given interesting results. The optimum time of application is found to vary with the locality. At Coimbatore, best results were obtained when the manure was applied one and a half months after planting, at Aduturai and Pattambi two months after and at Maruteru one month after.

The yield of the rice plant is influenced by two conditions, (i) the number of ear bearing tillers per plant and (ii) the size of these ears, and as will be shown later, it is the latter that plays a more important part. If the fertilizer is applied just at the time when the ear primordium is about to form, it has a direct effect on increasing the ear size. The time of ear formation should vary with the variety and the locality and hence the differences obtained regarding the optimum time.

CHAPTER XII

BOTANY OF THE RICE PLANT

Rice plant (Oryza sativa) botanically is a grass included in the great family 'Gramineæ'. This word *Oryza* may be said to bear some resemblance to the Telugu name, '*Vari*' and the Tamil '*Arisi*'. In the Spanish and Portugese languages the word for rice is '*Arros*'. The original Asiatic word *Erus* must have been modified into rice, riz, and reis. While the cultivated rices and a few of the wild rices are included under the species, *Oryza sativa*, there are three other species of rice, mostly wild, found in India and they are *Oryza coaractata* an aquatic plant growing wild in the Indus valley, *Oryza granulata*, growing on dry soils at altitudes of 3,000 feet in Assam, Burma, Bengal and Malabar and *Oryza latifolia* an aquatic plant again, found in Burma. There are certain other species mentioned by the earlier systematic botanists as *Oryza rufipogan*, *Oryza grandiglumis*, *Oryza minuta*, etc., but there does not seem to be much justification in taking them out of *sativa* as the particular characters justifying the name are all simple Mendelian characters. Some species are said to be indigenous to Africa and these have been obtained and grown in Coimbatore and it remains to be seen whether they are real species different from *sativa*. There is, however, one species *Oryza longistaminata*, also indigenous to Africa, which deserves a separate species status.

Shoot and root.—Germination of the seed has already been dealt with. The plumule comes out in 48 hours after soaking the seed in water and unlike other cereals it is the plumule (shoot) and not the radicle (root) that comes out first in rice. The plumule is white, tapering, much thicker than the radicle and is hollow in the centre, whereas the radicle is slender, long and solid. The radicle gives rise to the primary root system consisting of a number of fibrous and branching rootlets. The primary root system is temporary and is soon replaced by a secondary system which is produced from the first node of the plumule. The secondary root system is situated at a fixed level with reference to the ground. All later roots produced arise from the portion of the stem bearing the secondary system.

The plumule after coming out splits on one side through which the growing shoot emerges and gradually develops a green colour on exposure to light. The shoot which is nothing but a rolled up leaf in a rudimentary form begins to grow and after about 24 to 36 hours, unfurls the first leaf blade. This blade is encircled by a green sheath and has within it the growing shoot. The leaf sheaths are oval and consequently the stem of the rice seedling looks more distinctly flat than round.

The shoot comprises the stem, the leaves and the inflorescence, i.e., all portions of the plant above ground level. The so-called stem is formed of the several leaf sheaths overlapping one another. The stem remains concealed during most of its life by the leaf sheath on the top, and at the base by a mass of roots. The stem is very slow in growth and so short that it remains entirely underground and appears above ground only some weeks after planting. Unlike all cultivated rices, there is an underground stem developed in *Oryza longistaminata* and the plant can propagate itself with the help of the underground stems. The stem has a number of nodes from each of which grows a leaf and the parts of the stem between two nodes are called internodes. The internodes remain very short in the beginning and the upper ones, elongate first and the successive internodes become longer and longer. Each single stem is a culm and the internodes are hollow but may be practically solid when very short at the base of the plant.

Tillering.—Tillering is the development into new shoot of the bud remaining at the axil of each leaf. The tillering zone or the portion of the stem wherefrom the axillary buds develop into shoots is a small one confined to a few inches at and just below ground level. The internodes here are so suppressed that it would appear as if all the shoots spring from a common point. The tiller after it emerges from the sheath of the leaf, pushes it down which ultimately falls off. The tillers are usually produced on alternate sides of the main shoot. The tiller behaves as if it were a new individual and the vertical and lateral growth both of the mother and the tiller go on simultaneously. After some time a tiller may in its own turn produce additional tillers. The tillers as they develop into independent stalks grow along with the mother plant, mature and produce ear-heads. All tillers, however, do not develop completely and some of the very late ones may not produce any ear-head at all. The size of the ear-head also varies, the first formed tillers generally giving a bigger ear-head than the later ones. The stem of the plant does not grow, until the tillering phase is finished. When the tillering is nearly finished, the stem starts elongating rapidly, as the flowering time approaches. Though the tillers may be of different ages, the ear-heads on them come out and ripen almost at the same time as on the main shoot.

Leaves.—The leaves are long and tapering. The distinguishing parts of the leaf are the sheath, the auricle, the ligule, and the blade. The sheath is rolled into a cylinder enclosing all the younger parts of the shoot in early stages and later the internode only. It first remains small, but increases in length and thickness later. The blade is long and narrow from 12″ to 20″ in length, and about ½″ to 1″ broad at the broadest portion and remains flat. There is a junction joining the sheath and the blade, and at the base of the junction there are two sickle

shaped hairy structures encircling the internode called auricles. They may vary in size and may also be entirely absent in some varieties of rice. The ligule is a thin scaly projection appearing as a continuation of the leaf sheath for a short distance beyond the leaf junction. The number of functioning leaves on a stem may vary from four to seven and as the stem grows, the older ones below, first turn yellow and dry up. The top-most leaf enclosing the ear-head is called the boot leaf and is usually shorter and broader than other leaves. The sheath of the top-most leaf is first distended by the enclosed ear-head within.

Panicle and Spikelets.—The whole ear of rice is called a panicle or spike, and its axis is a continuation of the culm or stem. The stem of the panicle called rachis, is divided into a number of internodes and nodes from which branches of the panicle arise either singly or in a whorl. The branches may be simple or branched in turn and each final branch bears a number of flowers called spikelets. The panicles are erect at first, but as the spike-lets develop into grains they present a graceful arched form. The size and shape of the panicles may vary widely in different varieties.

Each spikelet is a complete flower having six stamens and enclosed by two well-developed glumes of which the inner is called the palea and the outer, the lemma. There are also two rudimentary empty glumes at the base of each spikelet. In some varieties these empty glumes may be as long as the ones bearing the stamens and pistil. The inner glumes bearing the essential parts may be green or of varying colours, though not all persisting at the ripening time. Inside the glumes at the base there are two fleshy small bodies called lodicules and a small ovary and two sessile stigmas which are long and featherlike. The flowers develop from the top downwards in each of the branches in the panicle. As the ovary develops, it fills up the whole cavity between the boat-shaped palea and lemma and this along with the two empty glumes constitutes a fruit or grain. The spikelet is laterally flattened so that the least diameter of the grain is its thickness. The palea may sometimes bear at its tip, a long awn. The palea and the lemma have a number of ridges and furrows and the edges of the two fit into each other so that they hold tightly the grain inside. The lemma and palea may be clothed with more or less stiff hairs, their number varying in different varieties.

Fruit.—The fruit or grain is enclosed by the husk, the lemma and palea, and lies loose inside when the grain is ripe. Under the husk, there is the fruit coat attached to the grain, which may be called the bran layer. The endosperm of the grain is mostly starch and in the so-called glutinous varieties, portion of the starch may be present in the form of dextrin. Rice fruit has no definite dormant period as it can germinate readily after it is perfectly ripe in the panicle. The number of spikelets in a panicle

is a varietal character and may be as few as 50 to 60 as in ***kuruvai***, ***kar***, etc., and may be as many as 200 to 300. The number more or less depends upon the length of the panicle.

The arrangement of the grains in the panicle may also vary in varieties, some having a lax panicle with the spikelets sparsely arranged and others having a dense panicle with the grains closely packed. The packed arrangement is usually to be found in very fine rices. The size of the grain may also vary widely and is the most definite varietal character.

Flowering, pollination and fertilization.—Rice flower is hermaphrodite, i.e., contains both the male and female parts. It is essentially self-fertilized, the pollen of a flower fertilizing the stigma of the same flower, but natural crossing is not rare. Pollination takes place just before or simultaneously with the opening of the glumes. The swelling of the lodicules by the absorption of water and the rapid elongation of the filaments, cause the glumes to open. The glumes remain open for some time, half to one hour, when the pollination is complete and the glumes close and do not open again. As soon as the glumes open, the anthers dehisce and shed their pollen on to the feathery stigmas which also grow and protrude outside the glumes. If the stigmas do not receive the pollen grains when the glumes remain open, the possibilities of the stigma getting fertilized later are very little and the result will be an empty or unfilled grain.

The opening of the glumes takes place between 10 a.m. and 12 noon, the chief factors controlling it being temperature and humidity. A warm sunny day hastens opening, while a cloudy day retards it. The flowering time of rice varies in different countries due chiefly to the climatic factors. There are also slight varietal differences. The blooming occurs earlier in the day in India, Java and Phillipines, than in Japan and America. The most active flowering takes place when the atmospheric temperature ranges between 80° and 84°F. Temperature either below 75°F or above 90°F retard flowering. The fact that temperature controls flower-opening has been made use of in Coimbatore in evolving a simple technique for artificial crossing.

It is the spikelets that are situated at the tips of the panicles that open first and the order of flowering gradually works downwards. It takes about a week to nine days for all the spikelets in a panicle to finish flowering, the maximum being recorded on the third or fourth day.

While usually pollination takes place immediately after the opening, due to defective anthers and want of pollen grains, the stigma may remain unfertilized but it maintains its receptivity even for six or seven days. There are stray instances of stigma getting fertilized even without the glumes opening and there is

even a *cleistogamous* variety in the Coimbatore collections in which the whole panicle remains enclosed inside the terminal leaf sheath which does not allow the glumes to open. Though seeds may get set in this, such setting is not always satisfactory.

Natural crossing.—While self-fertilization is the rule, natural crossing occurs freely, its percentage depending on the locality and varieties concerned. In Madras the extent of natural crossing was estimated to be somewhere about half to two per cent. Recently however, under exceptional circumstances, it has been found that this natural crossing may be as much as 10 to 12 per cent. In wild rices particularly, the dehiscence of the anther is not satisfactory and if the pollen also happens to be non-viable, crossing from the neighbouring plants may take place easily and it is in such cases that the percentage of natural crossing is high. Climatic factors also appear to play a large part in effecting cross-fertilization. Wind is one of the chief agencies in carrying pollen from one plant to another, but the distance to which such pollen is carried does not probably exceed six feet.

Artificial crossing.—For effecting artificial crossing the anthers will have to be removed before they dehisce and the pollen of another variety used to fertilize the stigma. The technique of crossing adopted by workers in the different countries varies, but the one now in use at Coimbatore appears to be most satisfactory and yields the maximum percentage of setting. A panicle which is on the second or third day of blooming is first selected and after removing all the fertilized spikelets at the top and the spikelets that may not open that day at the bottom, it is enclosed in a brown paper bag early in the morning. Due to the increase in temperature inside the bag, the glumes start opening much earlier in the day and since the anthers are not mature enough at the time, they come out and hang without dehiscing. These are caught hold of at the filaments by a pointed forceps and removed. When the pollen of the other parent is ready it is brought and dusted on to the stigmas of each spikelet and the whole panicle is kept in a cloth bag to prevent access to any foreign pollen.

During the first few days after pollination the endosperm in the single ovule grows rapidly and reaches its full length after which its other dimensions increase slightly. Its contents are at first liquid and consist of white starchy material. This is called the milk stage. As more material passes into the endosperm, this milk solidifies and hardens passing successfully the dough, soft and hard stages.

The time taken for the grain to ripen after fertilization varies somewhat with varieties. In early varieties of four months and below, the grain is fully ripe in 25 days after fertilization, but in later varieties this period varies from 35 to 40 days.

CHAPTER XIII

Rice Varieties and Classification

That there are several thousands of rice varieties actually under cultivation in India has already been pointed out. Most of the varieties grown have got their own vernacular names, these names sometimes denoting a particular characteristic of the variety. There is certainly a large amount of duplication, i.e., the same variety going by different names in different parts of the country and there are also instances of different varieties going by the same name in different parts. As an example of the former, may be mentioned the variety named *sarapalli* in Trichinopoly, *sornawari* in South Arcot and *swarnalu* in Godavari; an example of the latter is the variety *sirumani*. The *sirumani* of Tanjore is an entirely different variety from the *sirumani* of Chinglepet or Madura. Notwithstanding this, it has been found that the number of botanically distinct varieties is well over a thousand in Madras itself. New types are being continuously added. The chief agencies concerned in the production of new varieties are natural crossing and mutations. When two varieties cross either naturally or by artificial means the off-spring gives plants with enormous variations and as would be shown later, some of these variations may have combinations of characters not represented in the parents. The isolation of any such stable combination will give rise to a new variety. There may also occur in nature new mutations, variations occurring spontaneously due to changes in the germ structure giving characters not recognized before. The occurrence of such mutations are not very common but not unusual. Several mutations have been observed and isolated in Coimbatore.

The varieties differ from each other in (1) several morphological characters visible to the eye, which are inherited and which are not subject to much change due to the environment in which the plant grows and (2) several physiological characters which also may be inherited but which may be modified by the environment. The yield or the quantity of grain from a plant which is the main consideration in growing the crop, is related to the physiological characters. It is, however, the end result of a number of complex processes both environmental and hereditary, acting on the plant throughout the period of its growth.

Basis of classification.—The classification of rice varieties from the milling point of view has already been dealt with. There are classifications based purely on morphological characters. Apart from its scientific interest, such a classification is not of much value, to the cultivator. The morphological characters on which such a classification has been based are :—presence or absence of pigment in the different parts of the plant such as leaf-sheath, internode, glume, glume tip, stigma, leaf, etc. ; habit of the straw—erect, intermediate or prostrate ; nature of straw—short or long ;

A COLLECTION OF RICE VARIETIES AT THE PADDY BREEDING STATION, COIMBATORE.

RICE FLOWER AND ITS PARTS.

CHAPTER XIV

Root Studies in Rice

Just as in any other crop plant, the proper development of the root system is associated with corresponding vigour and productivity in rice. It has been observed that in rice the larger amount of tillering or production of secondary shoots is correlated with a better root system. Though rice may be an aquatic plant, its roots, as was pointed out already, do not belong to the aquatic type and require as much æration as the roots of a non-aquatic plant. The role of the surface film and the influence of its activity in supplying oxygen to the root have been discussed already. The root development was found to be the greatest where the conditions for this æration were perfect.

The root system of the rice plant consists of two kinds of roots, one, long, thin, flaccid, brownish and much branched; and the other, short, white, bold and unbranched. Both the kinds could be seen even in the seed-beds after about a fortnight's growth there. Adventitious roots appear early in the life of the plant and the primary root soon becomes indistinguishable. The roots are evidently in rings, emerging below the nodes, but the nodes are so close together in the region that the arrangement cannot be made out clearly. As new roots form, the old ones develop an impervious layer, first near the attachment to the stem and finally extending along the whole root, which then dies. At transplanting time, when the seedlings are pulled out, the roots are torn and the plant produces a fresh set of roots after transplanting. The roots remaining with the seedlings at transplanting time do not seem to function at all.

Root pruning experiments.—Experiments have been made at Coimbatore and Pattambi with pruning away all the roots at the time of planting and such pruned plants never suffered in comparison with seedlings that were not so pruned. In fact the quicker establishment of the seedlings in the transplant field depends upon the rapidity with which new roots are formed. If the seedlings are grown under hardy conditions, say, raised in a dry bed without much of water, the root development is poor and such seedlings are found to establish quicker than seedlings grown under more favourable conditions with plenty of manure and water. When seedlings are pulled out of the seed-bed and kept for a few days we can see new roots springing up at the bottom of the stem near the base.

Variation in root systems.—The depth of the root system depends upon the variety and the cultural practices adopted. In the broadcast field, the seed is left on the surface and the rooting

zone is confined to a few inches from the surface and this is one of the reasons for the broadcast crop lodging more easily than a transplanted one. While transplanting, the seedlings are thrust a few inches inside the mud and the rooting zone is also deeper.

The root system is generally poorer in the early varieties than in the late ones. Apart from the age of the variety, there appear to be variations according to, whether it is a low land rice or a dry land rice, whether it is a coarse or a fine one whether the soil is stiff clay loam or sandy, whether the variety has a stiff erect or a weak lodging straw, etc. The typical dry land rices develop a bigger root system than the wet land rices when grown under dry conditions than they do in puddle. In puddled lands, however, the typical wet rices develop a large root system. Quite unlike other crops, in rice it is found that the more the water-supply the greater is the root development. Generally a fine rice like *jeeragasamba* has a smaller root system than a coarse one of the same duration.

With regard to the relation of soil to the root development it is found that the root production is greater in clay soils than in loamy or sandy soils. Evidently in the very open soils where the drainage is very rapid the roots do not get sufficient oxygen supply and hence the development is reduced. Apart from the difference in root system according to whether the crop is broadcast or transplanted, the varietal difference is apparent. For instance, in the deep water rices which have comparatively a larger shoot system than any variety of similar duration, the root is very poorly developed both in quantity and depth of penetration. Strain GEB. 24 has been found to possess a more profuse and matted root development than any variety of similar duration and this might be a reason for its greater productivity. The preparation of the land for a second crop of rice after GEB. 24 has, on this account, got to be very thorough.

Comparing a short and a long duration variety, the production of roots is more in the former in the beginning, and the roots appear to concentrate on spreading in a zone down to four inches depth. In the long duration variety the root growth is more sustained and goes very much deeper, sometimes even to twelve inches. Generally the root development is in direct proportion to the time of ripening, the varieties ripening latest having the largest development. Observations made at Coimbatore have shown that, among varieties of similar duration but differing in height, the downward and the lateral spread of the roots is more pronounced in the taller than in the shorter varieties. Within a variety there is a definite and high correlation between the number of tillers and the number of roots per plant, the greater the tillering the greater being the root development.

Generally the increase in the number of roots produced continues up to the time the plant finishes flowering and shows a fall later. There appears to be however differences among varieties according to their duration. In varieties of four to five months' duration the number of roots per plant shows a fall as the late-formed tillers start dying off but in a variety of six months' duration the root development continues to be active for a very much longer period. In all varieties when once the grain has ripened, the roots start dying irrespective of their duration and there is no further root activity even if moisture is present in the soil. Provided the soil is not allowed to dry up completely after the harvest of the crop, the stubbles can be used for further propagation. If these are transplanted there is a fresh root activity and the production of new shoots and roots goes on simultaneously.

The root development is also related to the fertility of the soil and the manure applied to the crop. The root development is at its maximum when the fields are well fertilized with bulky organic manures like green leaf, cattle-manure, oil-cakes, etc. This must be due to the greater supply of oxygen. With regard to the different chemical fertilizers, nitrogenous manures like ammonium sulphate definitely encourage greater root development. Phosphatic and potassic fertilizers do not seem to have any particular effect, and in fact their application without sufficient nitrogenous manures appears even to inhibit the growth of roots.

CHAPTER XV

The Straw Character

Variations.—With regard to the habit of the stem, two or three definite types can be made out. There is the typical wild rice at one extreme where the stems remain almost flat parallel to the soil for a great portion of the season and bend later becoming erect when the ear-heads are formed. At the other extreme we have some cultivated rices where all the shoots remain grouped together as a clump assuming a position almost vertical to the soil. There are any number of varieties with the straw character representing several intermediate stages between these two. The prostrate or wild habit is not a desirable character. It has been found that the erect or compact habit of the straw is usually associated with a non-lodging nature.

Cultural practices and straw character.—The lodging or non-lodging nature of the straw is an important economic consideration in rice as in other cereals. A weak or lodging straw is undesirable. The initial high fertility of the fields, early planting and application of nitrogenous fertilizers are factors contributing to bigger yields. This object is, however, frustrated by the too rank initial growth which is indicative of future lodging, but this can be satisfactorily averted by adjusting the cultural practices. It was mentioned that in Godavari certain soils already possess the optimum conditions of soil fertility and in a favourable season the crop tends to lodge even before the ear-heads are formed and great loss occurs. Such premature lodging is usually counteracted by either cutting off a portion of the foliage in the early stages or allowing cattle to graze it down a little. It was pointed out before, that the whole stem consists of a number of internodes, a number of them condensed and remaining short at the bottom close to ground level and a few elongated internodes on the top. Favourable conditions contributing to premature lodging make the bottom internodes grow faster and longer in the early stages of the crop. The cutting of the plants arrests this premature growth and retards the elongation of the bottom internodes with the result that lodging is prevented. It has been found by experiments conducted over a series of years at the Maruter station that this topping does affect the yields though not probably to the same extent as lodging would. Minimizing the loss due to cutting consisted in adopting the practice judiciously, fairly early in the season, and not too low.

Adjustment of other cultural practices to prevent lodging consists in planting the seedlings wider apart where early planting is

inevitable, planting seedlings which have been kept for some time after they are pulled out of the seed-bed, and application of fertilizers in partial small doses instead of in a single big application. The *udu* cultivation described before, which consists of growing together an early and a late variety, also helps in preventing lodging in the late crop. The practice of double transplanting, previously referred to, is another method of dodging the problem of lodging.

Morphological and anatomical studies have been made at Coimbatore with regard to the problem of lodging in rice varieties. Great differences were found in the extent and type of lodging that occurred in the different varieties. While lodging is common in most of the economically superior types, it does not do much harm so long as there is no adverse wet weather prevailing at the time of harvest. The deep water paddies which have a straggling stem come down flat on the ground unless there is sufficient water in the field to support the stem. There are, however, certain varieties which do not lodge at all, even after the crop is dead ripe. Several of the Burma types that are available in Coimbatore collection belong to this group. Such non-lodging types are generally poor in tillering and are coarse-grained. These are characterized by stouter stems with a persistent leaf sheath closely adhering to, and covering a great portion of the bottom internodes. Sections of stems examined under the microscope show in several cases a special thickening of the cell walls on the boundary which probably helps the plant to remain erect.

Inheritance of straw character.—The problem of lodging is not of much consideration so long as the harvesting of the crop is all done by human labour which continues to be the practice all over the world except probably in America. Since, however, it is impossible to attain heavy yields with big ears without a corresponding improvement in the straw, breeding for stronger straw becomes important. The inheritance studies on the lodging and non-lodging nature of the straw would appear to show the latter to be a recessive character. The question of breeding types with good yield and non-lodging straw has received some attention at Coimbatore. Crosses were undertaken some years back between a good Burma type and one of the Coimbatore strains, to combine the high productive capacity of the latter with the stronger straw of the former. The work is now well advanced and certain strains showing the desirable combinations have been obtained and are undergoing trials in the cultivators' fields. Observations made on the progenies of the above cross have shown that non-lodging nature is usually associated with longer duration, greater height, poor tillering and high sterility. The association is, however, fortunately not absolute so that by patient studies extended over a series of generations it is possible to eliminate the undesirable from the desirable characters.

CHAPTER XVI

Sterility

Kinds of sterility.—One of the causes of low yields of rice is the occurrence of sterility, either partial or complete in its population. By sterility is here meant, the occurrence of unset spikelets interspaced with well set spikelets in the panicle. This is different from a special type of sterility known as '*sterile tips*' or 'sponginess' which sometimes occurs in certain rice varieties. Some of the spikelets either at the base or at the terminal portion of the panicle are white and rudimentary, both the ovaries and the anther sacs not being developed. This is a characteristic of certain varieties, and Co. 3, a strain from Coimbatore, often exhibits it in varying amounts. High fertility in the field also increases the incidence of '*sterile tips*.'

The ordinary form of sterility, where some of the flowers, in spite of their containing all the essential parts, remain sterile, is of common occurrence in rice. When grown under optimum conditions a large number of rice varieties exhibits very little of this defect, but certain others show it to a varying extent year after year. *Jeeragasamba* of the Tamil districts and *vankisannam* of the Kistna delta are two examples which always show a certain amount of sterility.

Sterility or unsetting is exhibited to the greatest degree by the wild rices. In these the spikelets are produced in abundance but few of them develop any grain. A large number of varieties in the Coimbatore collections has been examined for the amount of sterility occurring in them from year to year and it has been found that this amount varies from about 2 to 40 per cent. It is not known whether the awns produced by some varieties interfere with the proper setting of the grain or not, but the awned varieties generally show a fair amount of sterility though there are exceptions to this finding. It has also been found that several of the early varieties show sterility. There are also certain mutations that have been observed to exhibit sterility to an extent of 90 per cent.

Sterility and environment.—One of the chief environmental conditions that causes sterility has been found to be the season of planting or rather the time at which blooming takes place. Every variety has an optimum season of planting, and growing it in the wrong season, results in reduced yields, one of the contributing causes for such low yields being sterility. The effect of sowing and planting GEB. 24 and Co. 3, at regular intervals throughout the year has already been mentioned. Besides other observations the amount of sterility was estimated for each sowing.

The percentage of sterility was found to vary from 6 to 27 per cent. in GEB. 24 and 10 to 32 per cent. in Co. 3 according to the time of planting which varied from July to February. Although from the yield point of view it might be said that the earlier the sowings the better, it would appear that, but for the higher percentage of unsetting obtained, some of the later sowings could have proved even better. The sterility observed here had nothing to do with the vigour of the plant as the number of ears formed per plant was satisfactory even in some of the later sowings.

Too much of rain or cold spells at flowering time, or want of sufficient moisture in the field at this time when plants transpire most, are known to cause sterility in the plant. This is due to the climatic conditions interfering with the normal opening of the glumes and the dehiscence of anthers. There is also another type of sterility caused by too much of water in the field when the grain has nearly ripened. The presence of moisture induces additional tiller formation and production of small ears in such late tillers. These, however, do not have sufficient time to set and ripen seed and their contribution to the total yield is only unset chaff. The premature lodging of the crop mentioned previously also causes sterility.

Inheritance of sterility.—Apart from environmental influence, the unsetting is a hereditary character. It may happen that two parents used in a cross may be perfectly normal but the cross progenies of the same can exhibit unsetting in varying degrees. This is generally the case when any cross is made between two varieties differing widely in characters like duration, tillering, grain size, etc., or when they belong to two different zones having different climatic conditions. For instance crosses between Indian and Japanese varieties or between Indian and American varieties always produce unsetting. In fact sterility is one of the limiting factors in evolving high yielding types from cross progenies. In one of the crosses made at Coimbatore, the parents were normal but the F_2 generation exhibited sterility from 4 to 56 per cent. Though sterility may be a serious factor to contend against in making crosses between parents widely different, it has been shown in some of the other crop plants that the greatest possibilities of attaining success lie only in undertaking such crosses.

That sterility is an inherited character is particularly apparent from the association it shows with other known inherited characters in the progenies of crosses. In one cross made between a pigmented and a non-pigmented variety, the estimation of sterility in the F_2 progeny showed that the pigmented plants exhibited a higher percentage of sterility than the non-pigmented plants. In another cross where the progeny was segregating for duration and for the amount of emergence of the panicle from the enclosing leaf sheath, sterility was found associated with plants of later duration and

poor emergence of panicles. In still another cross involving difference in grain size and arrangement of the grain in the panicle (bunched or sparse arrangement), it was found in the progenies that the small grain and a closely packed arrangement in the panicle were associated with a greater degree of sterility. There are also indications that sterility is, to a certain extent, related to the glutinous character of the endosperm.

Detailed observations on certain varieties showing normally a certain amount of sterility, have shown that it is mostly confined to the later panicles and to the grains which flower at the end of the blooming period, i.e., those that are situated at the base of the panicle.

Cause of sterility.—The most common cause of sterility appears to be defective pollen. In crosses showing sterility, examination of the pollen in the F_1 always shows a large amount of aborted grains, while they are normal in the parents themselves. The anthers may also remain undehisced normally. Besides defective pollen another cause of sterility is the uneven maturity of anthers and stigma, simultaneous maturity being a necessary condition for proper setting. The unevenness may be either due to structural peculiarities as in certain wild varieties, or due to the abnormal climatic conditions of temperature, humidity, etc. Recent cytological studies in progress at Coimbatore have shown a relationship between the chromosomes, their number, structure, etc., and particular forms of sterility.

CHAPTER XVII

Shattering of the Grain

Besides sterility shattering of the grain is another contributory cause of lowering the normal yields of crops. A certain amount of shedding of the grain in all varieties at the time of harvest is inevitable but an ideal variety is one that does not shatter at all. The amount of shattering will depend upon the stage at which the crop is harvested. In an over-ripe crop the loss due to shattering is likely to be enhanced. A crop that is harvested while the straw is still green and then allowed to dry in the fields does not shatter its grain so badly as the same harvested after it is dead ripe. The loss due to shattering will be more in a crop that has lodged before it is quite ripe. In Tanjore where the harvest is done when the crop is dead ripe, the alternating heat in the day and the dew in the night which prevail at the harvest period add to the trouble of shedding which may be present even otherwise.

Varietal differences.—There are, however, great varietal differences with regard to this character. Generally the round type of grain, the *sirumani* of Tanjore, sheds much more than an oval or oblong grain like *Nellore samba* and hence the practice of confining the harvest operations for *sirumani* to the mornings when the crop is wet with the dew. The bundling of the sheaves and carrying them to the threshing floors are attended to in the afternoon when the sun has gone down slightly. Even among the normal type of grains, Co. 2, and Co. 3, are varieties which shed badly if harvesting is not done early enough. On the other hand the strain GEB. 24 can be left in the field as long as is necessary even after the straw has become over-dried and has reached the stage when it breaks into pieces at the time of harvest. It has been estimated at Coimbatore, that a loss of 5 to 12 per cent. of the crop may occur in the shedding varieties due to late harvest.

There is, however, another aspect to the problem of shattering. Since threshing is all done by human labour, by beating the sheaves against a hard surface, varieties that ordinarily shatter are the easiest to thresh. Even with a single beating all the grain comes off. While it is necessary to aim at a certain amount of non-shedding nature, an ideal non-shedding crop will be difficult to thresh and thus part of the advantage is counterbalanced by the extra labour that may be found necessary. The method of stacking the sheaves for two or three months before threshing which obtains in the Northern Circars makes the threshing operations easier, as the grains come off easily. There are certain types in the Coimbatore collections where the grains do not easily come off while beating.

Severe beating, only makes the whole panicles and portions of panicles to come off, rather than the individual grains. The wide variations of this character in the different varieties are being made use of at Coimbatore to study its inheritance in progenies of specially made crosses. A suitable and satisfactory method of estimating the degree of shattering in the plants has also been devised for this study. Breeding experiments have shown that it should be possible to evolve suitable types combining good yield with a reasonable amount of non-shattering nature.

The shattering depends to a large extent on the nature of the attachment of the grain in the panicle. This attachment consists of a depression at the base of the grain and a small projection of the stalk which fits into this depression. In varieties that shatter easily the depression is very slight as in the round *sirumani* grain and in varieties that do not shatter easily the depression is a little deeper with a longer stalk projection as in GEB. 24. In the Phillipines the non-shattering nature is found associated with varieties having grains with long awns.

We find the worst form of shattering nature exhibited in the wild rices. The grains shatter and come off the panicle even before they are ripe and any collection of grain must be done when the grain is only half ripe. The loss due to shattering has been estimated to go up to even thirty per cent in some parts of India as in the Malnad tract of the Bombay Presidency. A study of this character has led to the conclusion that this large amount of shattering is due to the contamination of the cultivated types by the wild rices growing in the swamps whose seeds get into the fields and freely cross with the cultivated ones producing a number of new forms carrying some of the wild characters. There are plants which for all purposes do not have any wild character except this shattering nature. The problem here is to get rid of the wild plants systematically and prevent any natural crossing taking place in the field. We have some difficulties with this wild rice (*vari*) in Malabar, and cultivators take special pains to get rid of it from the cultivated fields.

CHAPTER XVIII

Developmental Studies

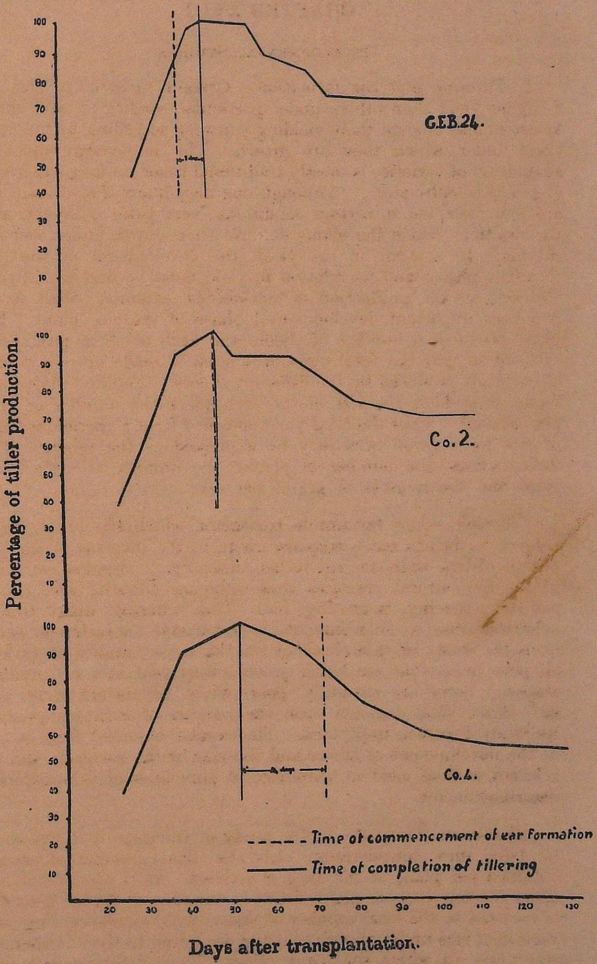
1. *Tillering and ear formation.*—Certain varieties of rice give a higher yield than others under particular conditions, and certain varieties also change their yielding capacity according to the conditions under which they are grown. The knowledge about the adaptation of varieties is mostly traditional based on long experiences of practical cultivators. Although one may know that certain rices are more adapted to certain conditions, very little is known about the reactions which the plants exhibit when grown under such conditions. In a study of the yield, the development of the plant in all its phases and its relation to yield must be first investigated. Tillering or the production of side-shoots, common to all cereals, is a very important developmental phase of the rice plant. Each plant produces a number of shoots and each of them produces an earhead so that the total yield of a plant is made up of a number of earheads produced by the different shoots. Another contributing factor to yield is the size of the earhead or the number of grains per earhead. Thus the total yield obtained from a particular variety of rice for a given area may be expressed as the product of the three factors, the number of plants, the number of earheads per plant and the number of grains per ear.

Tillering.—Any favourable treatment which the plant may be subject to, brings out a response more in the increase of the number of tillers than in any other character. Besides soil, some of the agricultural practices that influence tillering are, time of planting, spacing, manuring, etc. That tillering, apart from its behaviour due to environment, is a varietal character is evident from the study of this character in the large number of varieties, all pure lines, that are being grown every year at the Coimbatore station. Some are naturally poor while others are more prolific. Since yield depends upon the number of earheads produced, its study becomes important. The results obtained from a study of the development of tillers and the size of the earheads and their relation to final yield in a number of pure lines at Coimbatore are described below.

Studies in tillering.—In the study of tillering, it is not enough to take into consideration only the final number of earheads obtained per plant at the time of harvest. It is rarely that every shoot developed by the plant results in an earhead and the percentage of earhead to the total number of shoots may vary according to the variety of rice under observation and according to the environmental conditions, in which the plant grows. Ten of the varieties were

GRAPH 2.

TILLERING AND COMMENCEMENT OF EAR FORMATION.



planted with regular spacings and in each variety a block of about 300 plants was marked out. The tillering of each of these 300 plants was counted every week from the beginning up to the time of harvest.

Course of tillering.—In the case of a transplanted rice crop, the plants take sometime, six to ten days, to revive as indicated by the casting off of old leaves and the emergence of new ones. After the plants have established themselves, the buds in the axils of leaves in the main shoot develop into side-shoots, such development being confined to the buds near the surface of the soil. The zone where side-shoots are produced is restricted to half to one inch in length along the main axis and situated about one to two inches below ground level. If transplanting is done too deep the bottom most internode first elongates up to about an inch from ground level and then the production of side-shoots commences. If the tillers produced progressively along the main axis be called primary tillers some of the first-formed primary tillers may start forming side-tillers in their turn which may be called secondary tillers. In course of time the secondary tillers may themselves produce tertiary tillers. When the total number of tillers in a plant is considered it is always found that there is a definite proportion of these different classes of tillers making up the total. The actual separation of the tillers into groups becomes rather difficult at the later stages but still can be made out with some care.

The course of tiller formation appears to be almost identical in all the varieties studied, there being no strong varietal differences noticeable. During advanced stages of growth crowding occurs, with the result that the process of tillering with respect to one or more side-tillers comes to a standstill, while others more favourably situated, continue to produce tillers.

Active tillering commences about two weeks after transplanting and goes on rapidly for about four to five weeks thereafter. The period through which this activity continues is a varietal character mainly dependent on its duration. In a four months' variety the period may not extend beyond three to four weeks. Apart from the varietal characteristic, abnormal conditions like too much of spacing, late planting, excess of fertility in the soil, stem-borer attack, cause the normally dormant buds to get active and produce tillers and this prolongs the vegetative phase. Excess of water-supply either artificially, or due to rains late in the season, may accentuate a fresh tillering phase but such late tillering never contributes to yield.

Death of tillers.—When once the tillering phase has reached the maximum, under normal conditions, in spite of the ideal conditions for growth being present, some of the late-formed tillers start dying off. This is probably due to the mother tillers endeavouring

to successfully rush through the reproductive phase cutting off supply of nutrition to such late tillers. All the late and unwanted tillers are thus eliminated by the time the plant starts forming earheads. This procees of reduction is almost the same in all varieties. The final percentage of ears to the total tillers produced by the plant varies in the different varieties. In a late variety like Co. 4, taking over six months to ripen, this percentage is only about 60, whereas it goes up to 80 per cent in varieties like GEB. 24, Co. 7, etc., of five months' duration.

Tillering and yield.—Examining the yield per plant it is found that in several of the varieties, the increase in the number of functional tillers or ears is directly proportional to the yield per plant. In a late variety like Co. 4, however, this increase is not so regular. Though generally the yield per ear is almost the same in each of the plants with different number of ears, in certain varieties like GEB. 24 and Co. 7, there is a slight increase in the yield per ear as the number of ears per plant increases. It is possible that in these varieties the increase in the number of ears, is an indication of the plant's greater adaptability to respond to environmental changes which affect the production of ears.

Critical period of tillering.—If the ears formed follow the same order as the development of tillers, the plant produces enough tillers to result in ears even two to three weeks before the maximum tillering phase is reached. If we denote the particular stage in the tillering where the number of tillers formed is equal to the number of ears produced as the '*critical period*,' all tillering beyond this period is a waste. As any increase in the number of tillers per plant leads to a corresponding increase in the number of ears, enhanced tillering should result in enhanced yields. To get the maximum benefit the attempt must be to so adjust the agronomic practices to enhance the rate of tiller production as much as possible up to the time of this critical period.

Individuality of tillers.—If all the late-formed tillers are going to prove a waste, what is their function in the plant? A small experiment was conducted where, in a certain number of plants of a variety only a particular number of first-formed tillers—three, four, five and six—were left in the plant and all the rest removed as they were forming. Examining the yield per ear in each of these plants, it was found that it definitely increased as the number of tillers left increased up to a certain stage and then dropped again, and in every case the yield per ear was decidedly more than in the plant which was left without any pruning. This probably shows that any increase in tillering beyond a certain number does not conduce to higher yields and the removal of such superfluous ones contribute to increasing the size of the existing ears.

In another experiment an attempt was made to determine the individuality of the tillers and the relation between the sequence of tillers and their contribution to yield. The aim was to find out

the effect on yield by planting seedlings with three initial tillers, and also by removing the main, second or both the secondary tillers to elucidate the function of each. Periodical counts of tillers were made and the final yields determined. Though the yield of the plant was highest where all the tillers were left in tact, the reduction in yield due to the removal of the second or the third tiller was not very marked. When, however, the main tiller was removed the yield went down considerably. As regards the total number of tillers produced per plant, it was highest where all the tillers were left intact closely followed by the one where the third tiller alone was removed.

It was also observed that wherever the main tiller by itself or in combination with others was left to develop, the plant flowered definitely one week earlier than when the main tiller had been removed. This experiment definitely proves the advantage of the main tiller towards its contribution to total tiller production, total yield and earliness in flowering. If by any circumstances, say, stem-borer attack, the main tiller could not develop, the yield is sure to be affected.

II. *Development of the ear.*—A rapid growth in height of the tiller in the later stages, foretells the onset of the reproductive phase or the formation of ears. After a time all the tillers of the plant produce their rudimentary ears in quick succession, the interval of time, in the production of ears in the main, secondary or tertiary tillers being very much less than the interval observed in the formation of tillers themselves. A difference of two to three weeks in the ages of tillers will get dwindled to a few days by the time earheads are produced. In the later stages of tiller counts, a few plants with the average number of tillers for the week were pulled out and the parts examined to find out at what stage the ear formation commences. While the maximum tillering phase was reached at the same time for all the varieties studied, namely, six weeks after planting, the time of ear formation appears to be independent of tiller production, and is mainly a varietal character depending on its duration.

When ears are formed.—In varieties of less than four months' duration the ear formation in the tillers commences quite two weeks before the maximum tillering phase is reached. In varieties of 4½ to 5 months' duration like GEB. 24 and Co. 1, the ear formation begins a few days earlier than the onset of the maximum tillering phase. In varieties of 5½ months' duration like Co. 2 and Co. 3, the ear development synchronises with the stage at which the tiller production is at its maximum. In late varieties of over six months' duration like Co. 4, and Co. 8, there is an interval of over three weeks between the finishing of the tillering phase and the commencement of the ear formation. The knowledge as to

when the ear formation commences is very important as it leads to the judicious adjustment of any cultural practice, say the application of a quick acting manure like ammonium sulphate.

Effect of manuring on ear formation.—The experiment with regard to the time of application of ammonium sulphate has already been mentioned. The best time for applying the manure from the point of view of yield was found to vary in the different localities. For instance, at Aduturai the best results were obtained when the ammonium sulphate was applied two months after planting. When the tillering records of the experiment were examined it was found that both the maximum number of tillers per plant as well as the time at which such maximum was attained was different for the different times of applying the manure. The maximum production of tillers and the maximum percentage of functional tillers were recorded for the application of the manure two months after planting. As the ' critical period ' of tiller formation must have been earlier than the onset of the maximum tillering phase, the yield increase due to the ammonium sulphate must be attributed to bigger sized earheads. It is generally known from the application of nitrogenous fertilizers to cereals as a top dressing practised in the West, that the yield increase due to such applications is mainly in the shape of obtaining bigger earheads. The early application of the manure, say at planting time, hastens the tillering and the maximum tillering is reached much earlier than in the later applications. While a certain amount of hastening early tillering, i.e., before the arrival of the ' critical period ' is an advantage, hastening it too much by the application of fertilizers at planting time does not result in any advantage. In lands of above average fertility such hastening may even prove disastrous as it leads to rank growth and premature lodging.

The increase in the ear size by the application of a fertilizer is probably brought about in the following way. In the early formed tillers, the length of earheads formed and the number of grains per ear are almost the same. But in the case of the later-formed tillers, the number of grains per panicle decreases, there is a greater percentage of unsetting and the size of the individual grain is also slightly less. Application of the fertilizer at the time of the ear formation helps in overcoming these defects particularly in the late-formed tillers.

III. *How to make use of the knowledge about tillering and ear formation.*—The tillering studies thus point out, that, to get the maximum yields from a given area, both the number of ears per plant and the number of grains per ear must be increased. Of the two, the latter is found to be an even more important factor. To increase the number of ears per plant, the plant must be encouraged to produce tillers early and rapidly. Though early vigorous tillering may be a varietal characteristic, it can be induced even in others

by adding to the initial fertility of the soil and by the proper adjustment of the spacing given between plants.

Spacing, in fact, has a more profound effect on tillering than even manuring. When once early and rapid tillering has been achieved the attempt must be to increase the size of the ears formed by the tillers. This is best done by the application of a quick acting fertilizer like ammonium sulphate at a time when the juvenile earheads are forming. Since this will vary according to the variety and the soil conditions, the determination of the correct time of applying the manure can be done by actual tests in the locality with the variety. It is thus evident that a correct knowledge of the developmental phases of the plant leads to a judicious adjustment of agricultural practices and helps to get the maximum benefit.

CHAPTER XIX

RICE-BREEDING

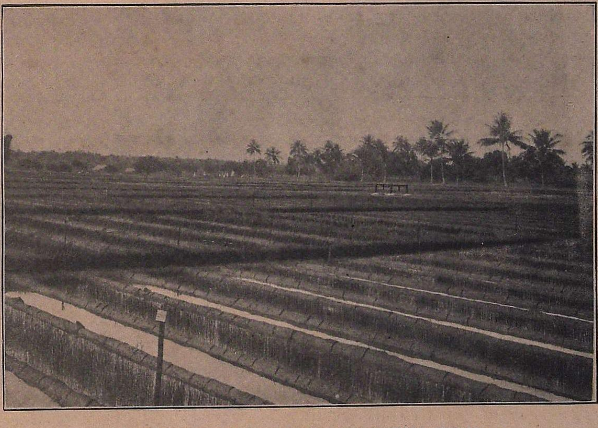
Methods of crop improvement.—The improvement achieved in any crop can be of two kinds, one due to 'nature' and the other due to 'nurture.' The nurture is the adjustment of cultural practices, which are methods of raising the nursery, methods of transplanting, methods of manuring, etc., and these have been dealt with already. By improvement is here meant a greater return for the same investment. While the adoption of improvements in 'nurture' might involve extra trouble or investment in taking to new methods of growing the crop, adoption of improvements in 'nature' involves invariably no additional trouble or expense. The improvement of 'nature,' i.e., 'breeding,' is what is usually adopted by any crop breeder. The lines of attack usually adopted by a breeder are what are known as selection and hybridization.

Sometimes even before attempting to start work on these methods, there is a particular method of work which the breeder unusually resorts to, to bring about desired results. This is what is known as 'introduction.' Sometimes even this simple process can give a tangible improvement.

Introduction.—This is nothing but introducing any special variety of rice from one tract into another. If by chance the conditions in the new tract are more favourable to the introduced variety it does well and probably gives a better return to the grower than the existing ones. If the trials are satisfactory, the variety spreads automatically and in course of time would replace the less profitable local kinds.

Past experiences with introduction.—This subject of introduction has received the attention of the local Agricultural Department even in the very early days of its work. We find mention made in some of the earliest reports of the Department about the introduction of a number of rice varieties into Madras from the Central Provinces, Bombay and Bengal. Of the several introduced varieties, *banku* and *rascadam* are the only two still being grown in Madras to some extent, the others having disappeared due to their unsuitability to the conditions. One chief difficulty in introducing varieties from one place to another is that the change of conditions causes great variations in the crop. Some times they become either longer or shorter in duration and do not fit in with the local cropping season. Even recently some of the best rices of Japan, Italy, Spain and America have been tried and have proved failures. They grow and put forth heads probably due

SEED-BEDS OF SINGLE PLANT SELECTIONS.



SEED-BEDS OF STRAINS UNDERGOING YIELD TRIALS.

to the hotter climate and longer nights, too soon to be of any economic use. But where the conditions are not widely different the introduction has sometimes proved a phenomenal success.

Examples of successful introductions.—Poombalai, a Tinnevelly variety, was first introduced to Coimbatore and Co. 2 a strain of this variety has proved a success in several other parts of the Province. Similarly *Nellore Samba*, a variety first introduced from Nellore, is now grown on a very large scale in the Tanjore and Trichinopoly districts. GEB. 24, a strain bred in Coimbatore, has been found suitable to varying conditions and has spread largely in Periyar tracts of Madura, the Hospet taluk of Bellary and parts of South Malabar. It has completely replaced most of the local varieties in parts of Mysore and Hyderabad. Recently among the large number of varieties that have been introduced from other provinces in India, one or two are proving exceptionally good and can well replace varieties of similar durations but with grain of poorer quality. We cannot pass any judgment on any introduced variety without trial for a sufficient number of seasons as sometimes it takes time to acclimatise itself to the new conditions.

Introduction where most effective.—The introduction is likely to be particularly useful where it is intended to meet some special needs of a tract such as a variety that can resist drought, a variety that can stand deep water conditions, a variety that will stand alkalinity, etc. The question of introduction is to a large extent dependent upon the peculiar needs and prejudices of people in particular tracts. What would pass as fine rice in one tract would be considered coarse in another. Some people prefer red rices while others would not even look at it. There are again certain special varieties in favour in particular tracts, some for their fineness, some for their peculiar scent emitted while cooking and others for their suitability for the preparation of puffed or beaten rice. Sometimes even if the introduced variety satisfies the condition for which it was meant, it does not take root and spread in the tract for other reasons. Such reasons may be that the people do not like the grain or that the grain does not have a local market. In certain cases an introduced variety may cease to give satisfactory performance after sometime, as for example, the deep water rices introduced from Bengal into Kollair tract of Kistna. Though they did well in the beginning, the ryots had to drop it later.

Plant breeding.—There are in existence to-day wild species and wild varieties of plants which have been preserved by natural selection or evolved either through mutation or natural hybridization and without man's interference. There are also old cultivated varieties which have survived up to the present time through the helpful and discriminating care of the early agriculturists, or have come into existence through unconscious acts of man. Plant breeding as a science and as an art is, however, of comparatively recent

origin. There are a number of noted investigators to whom the honour of discovering the great biological principles, which underlie the science of plant breeding, belongs. They are Lamarck, Darwin, Weissman, Hugo De Vries, Johansen and Gregor Mendel. We are particularly indebted to Mendel for the laws of heredity which bear his name.

The art of plant breeding was also established by a number of celebrated men. The work of these men has formed the foundation on which almost all the improvement work on crops now adopted in the West, has been based. Great advances have been made with regard to breeding in cereals like wheat, barley, oats, rye, maize, etc., in the temperate countries. Though the conditions under which rice is grown in the tropics may be entirely different, the principles of breeding which have been so successfully used in the cereals of temperate regions are applicable to rice equally well.

Regular breeding work on rice was commenced only in 1914 with the appointment of a special botanist and the opening of a special station at Coimbatore. The chief aim of plant breeding in rice as in any other crop is the production of new varieties which will bring to the grower a greater return than he is getting with the existing varieties. The policy is therefore based on a survey of the needs of the Province concerned for new varieties. Every cultivator wants better varieties and can also give some idea of his requirements. The breeder takes hold of these requirements and formulates definite lines of work and chooses from among the many varieties already available, the most desirable and practicable to work upon. The three methods usually adopted in breeding, namely, introduction, selection and hybridization, have been followed. The first has been dealt with earlier.

Selection.—Selection consists merely in the choice of the best individuals for the propagation of seed and it is by means of selection exercised through centuries that the cultivated cereals are in their present state of excellence. Selection in animals is well recognized and understood as even the most illiterate cultivator would desire to have his cow served by a good bull so that the progeny will be satisfactory. The principle applies equally to crops. Selection, in its restricted meaning, has a technical significance and implies the systematic choosing of specific plants for future reproduction, with the object of bringing about an improvement of type. It recognizes that there are endless variations in any ordinary crop and that no two plants are alike. Selection seeks to isolate those types of plants which approximate most nearly to the ideal and to choose systematically from the produce of these types, the variations which are likely to be of value. The principle of selection was adopted by the Chinese, it appears, even 3,000 years ago when the cultivators used to pick out the ' best ' plants for sowing in the following year. Formerly, it was considered that by repeated selection from the progenies of a plant,

great improvement was attainable. But the ideal was not reached because all the progeny of a single plant which is self-fertilized are genetically identical and no amount of selection in this can bring about any permanent improvement. This principle is the basis of the 'Pure line theory.' There have been instances of remarkable achievements in various countries due to the adoption of selection. This is particularly so in backward countries in the tropics where the field is wide and new. The same cannot be said of the Western countries where agriculture has already advanced and the cultivation is confined to the most highly evolved improved types.

Selection may be of two kinds, the mass selection and the pure line selection. While the former implies selecting groups of similar plants the latter starts with the single plant as the basis.

Mass selection.—Mass selection consists of the continuous and repeated selection of a number of best plants. It is supposed that by such repeated selection of a number of good plants, the race as a whole would be gradually improved. It may happen that the plants selected are better than others on account of some favourable environment, such as their having received more manure than others as a result of uneven distribution of the manure in the field, or having been given more spacing than others. However, the repeated and rigorous selection of the best plants would gradually confine the choice to permanently superior plants, and the general character will improve in the desired direction. This can be easily adopted by any cultivator. He will have to only take hold of good plants in the fields before harvest and use the grain of such good plants for seed purposes in the following year. Mass selection can be adopted as a start before pure line selection is taken up. In fact, in all the rice stations of Madras, mass selected seed is first multiplied and distributed to the cultivators and this is replaced by pure lines when they become ready after some years. It has been adopted at Aduturai, Maruteru, Pattambi and Berhampur. The improvement by mass selection being temporary, has got to be repeatedly done every year.

Pure line selection.—This comes in when the individual plant or individual ear is made the starting point. It consists simply in isolating individual plants of promising appearance and multiplying the seed of their types as rapidly as possible. There is but one initial selection followed by rapid multiplication of the progeny. Here the selection begins with a number of superior plants of a variety and the seeds from each plant are separately planted and kept under continuous observation. This enables a strict comparison to be made of the progeny of each selection so that in a few years the best strain of the selections may be determined and multiplied for future use. The method assumes that repeated selection is not necessary. The main underlying principle of the method is that the merits of an individual are to be judged by the performance of its progeny.

The principle of pure line selection may be illustrated in the following way. If we measure the heights of 1,000 individuals taken at random, add up the heights and divide the total by 1,000, we get the average height of these 1,000 individuals and let us say, it is 5′–6″. If, however, the several recorded heights are examined, they vary from 4′ to 7′; we find a few are extremely short, say 4′, some are at 4′–4″, still more at 4′–6″ and so on and we get the largest number of people having the height of 5′–6″. People taller than 5′–6″ also exist and the number of individuals in each of the heights 5′–8″, 5′–10″, etc., will go on gradually falling down and theer are a few with heights of 7′. On the same analogy, if we harvest a crop of rice from a field containing say, 1,000 plants and divide the total yield obtained by 1,000, we get the average yield per plant. Though the largest number of plants of this 1,000 will have only this average productivity there should be some which give very much less and some very much more than this average. The pure line selection aims at finding out the best individuals from among those which give larger yields than the average and multiplying the same for seed purposes. The principle is quite straightforward but the process involved in arriving at the best individual is complicated and involves special technique and can be managed only at the Agricultural Research Stations.

CHAPTER XX

Technique of Pure Line Selection

Before any selection is undertaken in any variety of rice, its importance in the locality, the methods of growing it as adopted by the cultivators in the tract, the chief characteristics of the variety, and any special points to be aimed at besides yield, are first ascertained by undertaking a survey of the tract where the variety is grown, by an experienced officer of the section. Supposing *sadai-samba* of Coimbatore district is the variety which has been decided to evolve strains from, the officer who does the survey collects small samples of *sadai-samba* seeds from different places of the tract where the variety is grown in a fairly pure condition and brings them to Coimbatore. The samples are all mixed and after raising a nursery, the crop is planted in singles with regular spacings, say 1′ × 6″, in one of the good uniform fields, about half an acre in extent. This bulk field is constantly under observation. The sample being ryots' seed would give rise to good, bad and indifferent plants, some late and some early, and plants of varying morphological characters. A large number of plants true to the type is marked out on the basis of duration, height, tillering, good stand, uniform heading, well filled grains, freedom from sterility, etc. Vigorous plants next to a gap in planting or to an uneven patch are not selected unless there are other desirable characteristics. The number of plants selected will depend upon the convenience and facilities available, but about 200 to 300 will not be too many. The larger the number selected, the greater are the possibilities of its including some of the really best individuals. Any amount of theorizing and set descriptions in the choice of plants may not be of much practical value. It is the trained eye and the knack of spotting out the right type that really count. An extra vigorous plant may prove a hybrid and with years of familiarity with the plant and its characters, it should not be difficult to spot it out. The observations for selecting have to be made quite early; when the grain is in the milk stage would probably be the best time to examine and mark the plants. Each of these plants is separately labelled, the heads alone harvested when ripe in small cloth bags, dried well, stripped and put into a wide mouthed bottle with a tin screw top. The stripping and bottling has to be done carefully to avoid any seed getting mixed. A small piece of naphthalene ball is dropped into each of the bottles before storing and this prevents damage by rice moths.

Second year.—The above finishes the operation for the first year. During the second year just before the rice season commences, the grain in the bottles is examined again to see if any selection had been included with red rice, awning or too much of unsetting, etc.,

and these are rejected. If the examination of the plants at harvest has been done thoroughly there will not be any necessity to do this later.

Preparation of seed-bed.—The seed-bed is first prepared thoroughly by repeated ploughings. Usually the seed-beds are manured with heavy doses of green leaves, up to 10,000 lb. per acre and after the leaf has thoroughly rotted, the odd bits of unrotted stalks left with the leaves are removed and then the field is levelled. first with the large board drawn by bullocks and later with a hand board worked by coolies. While the former attends to the gross levelling, the smaller board finishes it off. Then the field is marked out into strips 3 feet wide with a 2-feet channel between two. There is also a 2-feet channel all round the field on the borders. Each of these strips is again divided into beds 4 feet long by putting small cross-bunds. Each bed will then be 4 feet by 3 feet and this is usually enough for sowing 4 oz. of seed unless the grain is too small when the area may have to be more. The beds are again hand-levelled and a thin layer of water kept in them. When finally prepared the level of the bed is a few inches above the level of the channels. When the channels are flooded water should be able to get into the beds and when the water in the channel is let off the water from the beds should drain off into the channels on either side.

Sowing.—Two days before the actual sowing the naphthalene in the bottle is removed, a special paraffined cardboard label is put in and water is poured into each bottle sufficient to completely cover the seed. After about 18 to 24 hours the water is drained off from each bottle by inverting it over a piece of wire gauze. When the draining is complete, the grain in each bottle is packed, and the bottle arranged in a box or tray and left in the dark, for about 24 hours. Sometimes the whole tray containing the bottles may be covered with a wet gunny. When the seeds have started germinating which takes place in about 24 hours after the draining, the whole tray is removed to the field and the bottles with the germinated seeds are left on the bunds of the beds according to a definite order, each bed having been labelled previously with a bamboo stake. Then just before the actual sowing, the label of the stake and the label inside the bottle are checked and then the seeds are sown separately in each of the plots. Great care is necessary to see that no grain gets in accidentally from one plot to a neighbouring one. To get a uniform stand the seed is sown very evenly and slightly away from the bunds. The quantity of seed in each bottle may vary according to the size of the plant taken but during sowing, care is taken to sow the same quantity of seed from each of the bottles. The sowing is all done by the staff or trained coolies standing in the 2-feet channels.

Draining.—After the sowings are over the water in the beds is drained off by cutting a slit in the bunds on the sides of the channel. But if any splashing rain is expected water may have

to be retained in the beds as otherwise, the beating rain will bury the seeds inside the mud and the germination will not be satisfactory. Draining will have to be done carefully to prevent seeds from the beds getting washed into channels. The drying of the soil surface in the bed and indications of small cracks show the necessity to water the beds again which is done by flooding the channels first and allowing the water to get into the beds slowly. This water is allowed to stand for three or four hours and then drained off. For a week or 10 days this frequent watering and draining will have to be attended to carefully. By this time the germination will all be complete and water is thereafter allowed to stand permanently in the plots until such time as the seedlings are ready for planting.

Sometimes the seed-beds may require a weeding. Any insect attack will have to be carefully attended to. As the seedlings are growing, the preparation of the transplant field is taken up which should have been ploughed in puddle once and manured with green leaves if necessary. Repeated ploughings, four to five times, and a final levelling finish the preparation.

Pulling seedlings and transplanting.—When the seedlings are ready they are pulled out by women coolies under supervision. The seedlings of each bed are pulled out separately, tied into bundles with a string—say of plantain leaf sheath—and then removed to the transplant fields along with the labels fixed in the seed-beds. In pulling out, the seedlings on the bunds of the beds or on the edges of bunds are not included, to avoid any accidental mixing. Great care is again necessary at transplanting time and it is all done under the immediate supervision of trained staff.

The transplant fields are just marked off into strips with coir ropes and at the top of each strip the seedling bundles along with their label stake are put in. One planting woman gets into each strip and with graduated bamboo sticks which she keeps at the sides along the strings and in front, she plants the seedlings with uniform spacing one foot between lines and six inches in the line. Each strip is about 40 feet to 50 feet long according to the size of the field and contains five rows of plants and there is usually an alley space of 2 feet separating two strips. There is no selection allowed in the seedlings at planting, the women being asked to plant them as they come. The whole operation looks at first very complicated but when once the coolies are trained to it, they go on automatically and quite fast too. A woman can easily plant 12 strips of 50 feet by 4 feet or about 6 cents in a day of 8 hours. With ordinary planting without any regular spacing a woman may plant about 8 to 9 cents of land. The seedlings are all planted in singles. The planting is done with a thin layer of water which soon dries up. The third day after planting water is let into the fields and then drained off. This is repeated until all the seedlings

establish themselves after which time, water is allowed to stand in the fields permanently and the depth of water is gradually increased as the plant grows.

Observation.—If there are 200 single plants sown and transplanted there will be 200 observation blocks each 50 feet by 4 feet in the second year. One of the characters on which observation is necessary is the time of flowering. If the selection work is intended to get plants definitely earlier in duration, even in the first year before the plants are selected, the planted field is represented in a specially prepared squared paper with one square for each of the plant in the field. The rows and columns being previously marked in the field by means of stakes fixed at every 10th plant, a coolie walking between the rows of plants every alternate day, shouts out whether any plant has flowered or not. A fieldman remaining on the bund marks the date on which each of the plants flowered, on the squared paper. The day on which the main ear-head of the plant emerges out of the enclosing leaf sheath is taken as the day of flowering for that plant. From the chart so prepared it should be quite an easy matter to choose really early plants. During the second year observation, no detailed flower marking is done but the flowering time of a particular family is taken as the day on which more than 50 per cent of the plants have put forth their main heads. This is easily determined by any member of the trained staff. If a family is pure for flowering duration, the interval between the first flowering and the finishing will not be more than a week or ten days. If on the other hand it is not pure, the flowering instead of its coming on in a flush will be protracted and can be easily made out even from a look at the plot standing on the bunds. Any family impure for flowering duration is straightaway rejected.

When the flowering is complete, the lots are examined for the purity or otherwise of other characters like presence or absence of pigmentation, height of plant, tillering, length and nature of panicle, size and shape of grain, emergence of the ear-head, occurrence of sterility, and so forth. An examination of a few plants in each of the lots will show whether it is pure or not for these various characters. Small changes due to the position of the plant are differentiated from large changes that are inherited. All impure lots so detected are rejected. Some of the selections, though pure for the characters, if they are unthrifty with poor tillering, small ear-heads, etc., are also eliminated. After eliminating all obviously undesirable selections, tiller counts, i.e., the number of ear-heads per plant are determined for a sample, say of 25 to 50 plants, in the middle row of each lot and the middle three rows are harvested and the grain gathered after counting the total number of plants contributing to the harvest. Though a rough comparison may be made of the yields, it cannot be taken as the criterion for rejecting lots as no valid yield comparisons are possible with single plots.

While the rejection of families based on impurity for characters actually observed, is quite valid, other rejections will have to depend entirely on experience and eye judgment. Elimination of lots in the second year will have to be drastic as otherwise the material to be handled will be too unwieldy to manage.

Third year.—If supposing out of the original 200 lots, 150 get eliminated in the second year the problem from the third year onwards is to determine which of the remaining 50 multiplied and distributed will give a greater return to the cultivator. The yield trials begin from this year. In the first year such an yield trial with 50 lots can only be in a rough and simplified form as regular trials with replicated plots will take too much space. Usually a simple form of trial adopted is to grow them in blocks as in the second year with all due care taken in sowing and transplanting, with a block of a control for comparison between every two strains. The control generally used is the bulk crop from the ryots' seed obtained first. The seed of this will have to be raised in the seed-bed with the same care and uniformity as for the selections. Sometimes instead of using the bulk which is a mixture of samples obtained from different localities, the seed from any particular locality found to be the best by actual yield trials on the station is used as the control. In this preliminary yield trial since there are no replications the yields of each of the strips have to be compared against the yields of the adjacent controls. Though it may not be very accurate, it gives fairly satisfactory results and is of use in eliminating and bringing the number of selections from 50 to a reasonably small number with which regular yield trials with replications can be undertaken later. Twenty is about the maximum number which can be taken on for regular yield comparison from the fourth year onwards.

Fourth year to sixth year.—The method of conducting yield trials with transplanted rice has undergone investigations for a number of years and it has now been standardized. Same quantities of seed from each of the strain and the bulk from which the plants were isolated are sown in regular well prepared seed-beds of equal sizes. Before sowing, the germination of the seed is tested as otherwise, unequal germination will affect the stand and result in uneven seedlings and hence differences in yield. The strains are split into three or four groups according to convenience, and size of the transplant field available, and each group is planted in one or two fields, the strains and control being planted in 40 feet by 4 feet strips distributed in a random manner in blocks and repeated six to eight times. If space permits the number of repetitions may be increased up to twelve. Reduction of the plot size to 20 feet by 4 feet has been found to give equally accurate results and allows for larger number of repetitions for the same area. The plants are put in 6 inches each way in the strips and there is an interval of one foot allowed to separate two strips. At harvest the middle

seven rows alone are taken rejecting the two border rows. When the crop is ready for harvest each repetition is harvested and threshed separately and the grain dried to constant weight and then weighed. The determination of the yields of the several plots individually helps in understanding the reliability of the experiment. Strains, which give a definite 10 per cent. increased yield over the standard are taken as promising and the trial is repeated with them rejecting the rest. To allow for variations in the season the yield trial is repeated for at least three seasons.

Seed multiplication.—During the years when yield trials are undertaken, the strips of different strains are planted quite close together and there is sure to be contamination by natural crossing between plants in adjacent strips. To overcome this, besides what is planted for comparative strips, a separate block is planted of each of the strains undergoing trial. It is only the seed from the centre of these blocks that is used for the next year's comparison and seed multiplication. Towards the closing stages of the yield trials when the number of strains gets reduced to two or three only, larger blocks are planted of these so that enough seed will be available for larger trials and multiplication.

It is the most outstanding of the strains that is finally retained, multiplied and distributed as a strain under a station number. A ten per cent. increase is taken as the minimum, as any increase of yield of less than ten per cent. is not likely to be appreciated by the cultivators.

District trial.—Recently with qualified staff available in the districts to undertake and carry out fairly accurate yield trials in ryots' fields, the last stages of trial on the station are supplemented by actual trials on cultivators' fields in the tract in as many centres as possible. Sometimes when this district trial with a few of the best strains is conducted at a number of centres in the tract, it is found that while a particular strain does well in one centre, another strain does equally well in some other centre. Thus the district trial is found to be of help in determining the variable suitability of the different strains to different conditions obtaining in the tract. Even where actual yield trials are not possible some quantity of the seed of the improved strain is given to one or two cultivators in the tract to make them grow it in their fields and their opinion regarding it is elicited. When once the cultivator is convinced of the superiority of the strain by the actual growing of the strain in his fields, there is no further trouble except the difficulty of meeting the demand for the supply of seed which increases very rapidly. Apart from the yield tests which are carried on in small plots, the strain must be grown on a big field scale and it is only then it gives a good idea of its characteristics. Yields are often expressed as so many pounds of grain per acre. With small plots this can only be a calculated figure which may be exaggerated. It is therefore necessary to grow the strain on a large field scale at a sufficiently early stage.

Scrupulous care in maintaining the purity of seed cannot be expected of the ordinary cultivator. There are inherent difficulties with regard to seed-bed areas being confined to definite localities near the village, and the existence of a common threshing-floor for the whole village. Where a number of varieties is handled, mixing of the seed in seed-beds and threshing-floors is inevitable and this, combined with the natural crossing taking place in the fields when odd plants are growing mixed in the crop, causes the purity of the seed to deteriorate. At the Government stations pure stocks of all the seeds distributed to the ryot are always maintained and these by multiplication and distribution help to maintain the purity of the strains. It will never be possible to meet all the demand for seed from the Government stations. Ryots can, however, multiply the seed and maintain the purity of strains if the instructions given in Chapter XXVI are followed.

Time taken to evolve strains.—The technique of evolving strains described has been adopted in all the strains so far evolved and distributed in the Province. Of these GEB. 24 and Adt. 8 are not mere selections. Appendix A gives details about these strains, the varieties they were selected from, and the conditions under which they have been found to do well. It is seen that it takes roughly, 7 years, before a strain can be released for distribution. It should be possible to save a year by a slight modification in the technique. Instead of bringing ryots' samples of grain and growing them on the farm, actual single heads can be directly selected in the ryots' fields. Since we cannot be sure whether the plants are always planted in singles under ryots' conditions, it is rather risky to take single plants. Single heads obviate this difficulty. These heads after examination at the station are sown and planted separately for observation in the first year and the preliminary yield trial can begin from the second year onwards. The quantity of seed in a single head being limited, the first year's block will be small, and will not contain more than 200 plants at the most. Greater care will therefore be necessary to spot out and reject natural crosses in the early stages but it is not an unsurmountable difficulty.

Purpose of selection.—Increased yield has been the sole criterion in the evolution of strains. While several of the strains have recorded a minimum increase of about 8–10 per cent. yield over the unselected seed others have given even greater increases like 15 to 20 per cent. While many of the important commercial varieties of the Province have been tackled, there are still tracts having varieties in which pure line selection will be worth undertaking. The strains already evolved have spread over large areas in the different tracts and an increased yield of a minimum of 10 per cent. in the total production by the growing of strains has been demonstrated. Sometimes, besides yield, the pure line selections may serve the purpose of meeting other desirable economic requirements. For instance earliness in duration without sacrificing

yield is an urgent requirement in some tracts. In Tanjore the strain of *kuruvai*, Adt. 3, does not give definite increased yield over the ryots' seed under all conditions but its chief merit lies in the fact that it matures ten days earlier than the ryots' crop, which is a great advantage. It has spread and become popular more on this account. A strain of *garikasannavari* evolved at Maruteru in addition to its higher yield is also slightly earlier than the ryots' crop and thus has the double advantage. It is found that it is quite possible to knock off a week to ten days in the duration of the crop by pure line selections only. In some cases a strain even if does not register a definite increased yield, being the produce of a single plant originally, flowers and ripens in the field uniformly and the grain is uniform. Uniform flowering and ripening are advantages easily recognized by the cultivator and uniformity of grain size and freedom from red rice are advantages valued from the trading and milling point of view. Though increased yield was the only consideration in the strains it has been found that several of the strains, besides giving higher yields also possess some useful ancillary characters as better quality rice, resistance to diseases, good straw, non-shattering grain, etc. In Burma great attention is paid to the milling qualities also in making selections. There is a great milling industry and a large export trade of milled rice from Burma. Though yield may satisfy the grower, the selection has to possess good milling qualities, i.e., freedom from breakage.

It must be emphasized that the weighing of the produce and determining the yield is not the only criterion of the superiority of a strain justifying its release to the cultivators. The straw yield is not usually taken into consideration except in the final stages of trial though the character does form one of the important points for observation in the crop. Habit and lodging have to be considered and when the strains differ among themselves with regard to these straw characters, the one combining yield with good straw is always preferred.

In certain rice tracts the quantity of straw obtained is certainly a consideration. In such places high grain yield alone may not satisfy the cultivator. There have been complaints in certain places about the poor straw yield of one or two of the strains distributed, but the fact that such strains have still spread must be due to several other more important merits which they possess. Sometimes cultivators make differences even in the quality of the straw. It is said that some straws are not so freely eaten by cattle as others. While coarseness may go with rigidity and capacity to stand erect, only fine straw will be preferred for feeding purposes. There are certainly differences in the quality of straw among varieties but it is doubtful whether any large differences can exist among strains of a particular variety except probably in quantity. Moreover, there is no possibility of undertaking selection with the idea of improving the quality of straw.

Husking test.—When a large number of pure lines from a variety is being tried for yield differences, we have to get an idea of the possible differences in the percentage of husked rice to whole grain. Big differences exist among varieties with regard to this character and it has been found that there are differences even among strains of the same variety. High percentage of husked rice to whole grain is an important consideration. Husking by the ordinary wooden pestle and mortar is not convenient for dealing with very small quantities of grain. A special wooden hand mill has been improvised which is found to be quite satisfactory. The mill, consisting of two parts, upper and lower, is made of some hard-wood. The upper revolving part is a disc of about 3 inches in thickness with a handle at one side for turning. A central hole widened above into a funnel shape, serves as a feed hole. An iron collar, fixed across the feed hole, acts as a bearing for the iron rod, fixed vertically in the lower part, about which the disc revolves. Sufficient clearance for the grain to pass is allowed between the rod and the narrow end of the feed hole. The lower part is a simple cylinder of about a foot high, heavy enough to stand firm when in use. The opposed surfaces of the two parts are corrugated with radial grooves. These are V sections, cut about a quarter inch deep and of the same width at the edge where they are half an inch apart and tapering towards the centre. The working surface of the lower part is sloped slightly from the central peg so as to be convex and the upper part is correspondingly concave. The surface wears quickly but can be deepened occasionally.

It is only the husk that is removed in this mill, the bran layer remaining in tact, so that the percentage determined with this mill will always be somewhat higher than with the pestle and mortar. While the percentage by weight is determined by directly weighing the rice and the husk obtained from a definite quantity of whole grain milled, percentage by volume is measured by first putting the whole grain into a narrow cylindrical or rectangular graduated glass jar, taking the readings and then doing the same for the rice obtained after milling.

The examination of the rice also gives some idea about its quality. Differences in hardness are easily made out and it can be easily verified by pounding the shelled grain with the mortar and pestle. With a definite number of strokes by the pestle, the percentage of broken rice obtained in the different samples gives an idea of the relative hardness.

Cooking test.—This is also usually done in the laboratories before the strains are released. Definite weighed quantities of pounded rice after shelling are first put in a copper cylinder open at top, their volume measured and then three to four times the volume of water added to them and the whole cylinder is put on a water bath for cooking. The bath can take four cylinders of the same dimensions at a time and the following points are taken

note of in cooking: the time taken to cook, the volume of the cooked rice, the volume and consistency of the supernatent liquid that has to be drained off after cooking and the consistency and appearance of the cooked rice. All these points give information about the cooking quality of the rice which will be of help in eliminating or retaining strains.

Special appliances.—In connexion with the breeding technique, it will be found necessary to have the undermentioned special appliances. Mention is not made here of the variety of bamboo stakes, coir ropes, etc., as they need no special attention.

It was mentioned that single plants are first harvested in cloth bags which after drying are stripped and put into bottles. Thus a large number of cloth bags and wide-mouthed tin screw top bottles of capacities from 4 to 20 oz. will be necessary. Before bottling, the grain may have to be cleaned of the chaff and for this small winnows made of thin metallic sheets are very useful. Ordinary bamboo winnows are not satisfactory as they may harbour grains in their interstices.

During threshing, the sheaves of small plots have to be beaten separately and this is done on a masonry floor and inside a rectangular wooden frame with three sides and open at bottom and top. After each lot is beaten out, the frame is removed, the grain is collected and put into receptacles for drying and weighing. The cleaning of the grain is best done by large winnows of metallic sheets. For collecting the grain, even baskets specially made of zinc sheets can be used. For drying the grain shallow metallic trays will be necessary. The storing of the grain in small quantities, say, up to 20 lb. is best done in ordinary kerosene tins provided with a lid. For very small quantities round coffee tins with tops are found very satisfactory. For quantities above 50 lb., a bin made of zinc sheets with a lid on the top is found useful. Such bins may be made of different sizes to hold 100 to 500 lb. of grain.

The wooden mill used for the husking test and the copper vessel for the cooking test have already been mentioned. An ordinary wooden pestle and mortar will also be required to determine breakage in milling.

Balances of sorts will be required for the different stages of work. To weigh the produce of single plants a small 'cement' or 'sand balance' costing about Rs. 60 has been found very satisfactory. For weighing grain and rice in the husking test a druggist scale to weigh up to 5 lb. may be necessary. For weighing the produce of trial plots a bigger balance to weigh up to 56 lb. is necessary. In this there must be a platform instead of the ordinary scale pan on one side so that the kerosene tins with the grain inside can be placed on it for weighment. Finally for weighing still larger quantities, the ordinary portable platform machine to weigh up to 3 or 5 cwt. can be used.

PLANTING OF TRIAL PLOTS WITH UNIFORM SPACING.

HARVESTING OF THE TRIAL PLOTS.

For measuring length and breadth of grain, an ordinary calliper with a vernier arrangement to measure up to one-tenth of milli-metre has been found quite satisfactory.

Limitations of selection work.—The selection work has, however, one important limitation in that we cannot be sure that a strain doing well in one centre under a particular set of agricultural and climatic conditions will behave equally so under a different set of conditions. It is very rarely that we come across a strain like GEB. 24 which does well under a wide range of conditions. As we know, the rice-growing conditions vary widely in Madras. This should mean that the selection work must be undertaken in the respective tracts.

Sub-stations.—This aspect of the question was realized quite early enough and hence the expansion of the Coimbatore work took shape by the opening of a number of sub-stations one in each of the important rice tracts of the Province. While the work at Coimbatore includes all aspects of study of the rice plant besides simple selection, the work of the sub-stations is mainly confined to selection work in the important local varieties besides a study of the agronomical problems like cultivation and manuring of the tract. The first sub-station was opened at Aduturai for the Tanjore district which has a million acres under rice every year. Eleven strains have been evolved at this station so far and these have been distributed to the people in the district and even at a modest estimate it can be said that more than 50 per cent. of the rice area in this district is now grown with Aduturai strains.

The next sub-station was opened at Maruteru for the Kistna-Godavari deltas and eight strains so far evolved have been under distribution in the tract since 1932. The third station was opened at Pattambi for Malabar and South Kanara and ten strains have just been released for distribution after the necessary trials at the station and in the district. Like Malabar, Ganjam is a district which, though having a large rice area, always records a poor acre yield. A station was opened at Ganjam in 1932 and good progress has been made in the evolution of strains suitable to the tract.

The necessity for undertaking selection work for particular tracts in the tract itself has been pointed out, but the opening of sub-stations on the model of the present ones for each tract cannot go on indefinitely. While certain important tracts like Chingleput may still justify the opening of such sub-stations, there are others where the rice-growing areas are rather limited. For these areas we might probably have small temporary farms of 5 to 7 acres in extent on leased land with a rather limited subordinate staff. On such small stations besides selection work for the tract, trial of strains evolved elsewhere in the Province and experiments on local cultural and manurial problems might be undertaken. A large number of such small testing centres is an

important feature of rice-breeding work carried on in Ceylon and Malaya. In Western countries there are special organizations to carry out trials of strains evolved by breeders in different parts of the country and farmers are easily found to carry out such trials and make the results available to the experimenters. The conditions obtaining here are different and it is sometimes found difficult to get a few landowners to agree to try the strains on their lands even when the work is to be managed for them by the Department.

There are certain minor tracts still where the rice-growing conditions are not very different from those obtaining at Coimbatore. Work for these tracts might be done at Coimbatore. That it is possible to do this successfully to a limited extent has been demonstrated. The material for the selection is first obtained from the tract and the later stages of field trials are duplicated both at Coimbatore and at some centres in the tract. So long as the final distribution of any strain is made to depend upon its successful performance in the tract itself there is no risk or waste of time involved.

CHAPTER XXI

Hybridization and Genetics

We then go to the next aspect of breeding, namely, hybridization. Hybridization may have two objects in view—(1) to bring about greater variability than what exists and (2) to synthesize in one variety certain desirable characters observed in two or more varieties.

It sometimes happens that certain varieties do not offer any scope for improvement by pure line selection. By long unconscious selection by the cultivator himself a variety may have attained a certain stage of excellence that any selections made in it do not show out any merit, i.e., the variation between individuals in the population is not large enough to give the breeder a chance of getting at a really good plant. *Sirumani* and *nellore samba* of Tanjore are good examples of this condition. Repeated attempts made to evolve high yielding strains from either of these varieties have not proved very successful. Hybridization or crossing these varieties with other similar varieties is the only possible method of increasing the variations in the F_2 generation so that the breeder will have a fair chance of coming across a really good yielder. The principle of hybridization for either increasing the variability or the production of new combination of useful characters is based on the famous laws of Gregor Mendel. The study of the inheritance of characters in the progenies of crosses is called Mendelism.

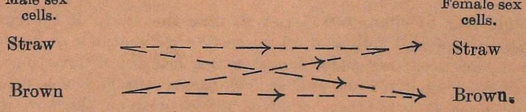
Mendelism.—Mendel's laws of heredity which were obtained from his studies on sweet peas over seventy years ago had remained unnoticed until the beginning of the present century. Before this time the breeder had nothing to guide him. Since the rediscovery, the principles have been greatly utilized in the study of the inheritance of characters in a great number of plants. Rice is a suitable crop for illustrating Mendel's principles and an account of it may be given here.

Single pair of characters.—Let us take the study of the colour of husk in rice and follow it in successive generations of a cross, between two rices, say *sadai samba* which has the ordinary straw-coloured husk on ripening and *nellore samba* which has a brown-coloured husk on ripening. A cross made between the two (the F_1, a term used in genetics), no matter what the mother was, either *nellore samba* or *sadai samba*, has only straw glume and is indistinguishable from the *sadai samba* in colour of glumes. This F_1 or hybrid plant by self-fertilization, i.e., the pollen of the same plant fertilizing the stigmas in it produces a large number of grains. When these grains are sown and plants raised from them, the F_2 generation, we get two types of plants one with straw glume like *sadai samba* and the other with the brown glume

like *nellore samba*. These straw and brown glumed plants appear in definite proportions. On an average the two sorts appear in the proportion of three straw to one brown. No other types occur. The characteristics appearing in the offspring of the hybrid plant are solely those found in the parent plants. Grains taken from individual plants of this generation and sown separately show the following results. Those having brown glumes give nothing but brown-glumed plants and in spite of the fact that one of the grand parents had a straw glume, this feature fails to appear. On the other hand, those taken from plants with straw glumes may either give rise to only straw-glumed plants or they may give both straw and brown-glumed plants. It is impossible to say from the appearance of the straw-glumed plants whether they will breed true to type or throw a mixed offspring. They are, so far as appearance goes, identical and the difference between them, can be made obvious only by growing the seed. This shows that plants may look alike and yet behave differently when the seeds are sown.

Many of the distinguishing characters of rice show this simple form of inheritance. It may be stated that when any particular feature fails to show up in the first cross, F_1, then all plants showing it in the next generation will breed true to it straightaway. The feature which fails to show up is called the 'recessive character,' the alternative 'dominant character' being used to describe the feature which completely masks the recessive in the first cross. In the F_2 generation there are two kinds of dominants, the 'pure dominant' which breeds true to type, the straw glume in this case and 'impure dominant' which on sowing produces a mixed offspring of dominants and recessives, straw and brown glumes.

How the F_2 generation contains definite proportions of straw and brown-glumed plants can be explained. The sex cells produced by the hybrid plant (F_2 generation) bear either one or the other of a pair of characters, in this case straw or brown. The male sex cells—the pollen grains, carrying either straw or brown may fertilize female sex cells—egg cells also carrying either straw or brown. The possible combinations of these sex cells are shown below :—



They are (1) straw × straw; (2) straw × brown; (3) brown × straw and (4) brown × brown. Two of the four possible combinations straw × straw and brown × brown, give rise to true breeding plants, the other two straw × brown and brown × straw give plants which are similar to the first cross and show only the dominant straw colour. So far as appearance goes they are counterpart of the true breeding straw and consequently in every four plants of the F_2 generation, on the average, three are straw glumed and one brown

glumed and of the three straw-glumed plants one will breed true to type: the other two behave like the F_1 and throw brown-glumed forms.

Two pairs of characters.—The above example may not have any economic interest but the possibilities can be exemplified when two pairs of characters are taken into consideration. Suppose the *sadai samba* with white rice was crossed to a brown-glumed variety having red rice. The inheritance of red rice and white rice is also similar to colour of glumes. The hybrid plant (F_1) is red rice and the F_2 gives red and white-riced plants in the proportion of 3 : 1. But the glume colour is not associated with rice colour so that the F_2 of this cross will give four kinds of rice plants :—

(1) Straw glume red rice.
(2) Straw glume white rice.
(3) Brown glume red rice.
(4) Brown glume white rice.

In (1) and (4) the parental characters have been regrouped and they are new forms. (2) and (3) are combinations representing the two parental forms. Their occurrence and the proportional representation is explained by the fact that the sex cells of the hybrid (F_1) carry either the one or the other of a pair of characters. There are four possible types of pollen grains and egg cells. These are capable of giving 16 combinations, for as shown below, each of the four kinds of pollen grain can unite with all four kinds of egg cells :—

Pollen grain.	Egg cells.	Appearance of the resulting F2 plant.	Remarks.
Straw red ..	.. Straw red ..	.. 1. Straw red	.. Pure.
	Straw white	.. 2. Straw red	..
	Brown red ..	.. 3. Straw red	..
	Brown white	.. 4. Straw red	..
Straw white	.. Straw red ..	.. 5. Straw red	..
	Straw white	.. 6. Straw white	.. Pure.
	Brown red ..	.. 7. Straw red	..
	Brown white	.. 8. Straw white	..
Brown red ..	.. Straw red ..	.. 9. Straw red	..
	Straw white	.. 10. Straw red	..
	Brown red ..	.. 11. Brown red	.. Pure.
	Brown white	.. 12. Brown red	..
Brown white	.. Straw red ..	.. 13. Straw red	..
	Straw white	.. 14. Straw white	..
	Brown red ..	.. 15. Brown red	..
	Brown white	.. 16. Brown white	.. Pure.

The appearance of the F_2 plants as given above will show that there are nine straw red, three straw white, three brown red and one brown white. Of the nine straw red, showing the two dominant characters, only one is capable of breeding true to type. These constitutionally distinct forms are alike in appearance and the isolation of the true breeding type can be managed only by sowing a large number of F_2 families and determining from their progeny which of them was built up of the two dominant characters only. Since this type occurs only once in nine times on the average, a

large number must be grown. The straw red type resulting from union (2) will breed true to straw character but its progeny may have either red or white rice, the two types occurring in the proportion of 3 of the former to 1 of the latter. Since 1 of every 3 will breed true a true breeding straw red can be obtained by sowing the grain of a small number of such plants. Number (3) will breed true to red rice but will give in F_3 3 of straw to 1 of brown. Number (4) will behave like the original F_1 and throw all the four types.

The brown white type which is recessive for both the characters occurs only once among 16 individuals and breeds true to type at once. All these plants can be harvested together if necessary and grown in bulk with the certainty of getting a pure crop in the F_3 generation. This rapid multiplication is, however, not possible with types showing one or the other or both of the dominant characters. Another generation must be raised to find the true breeding form.

Three or more pairs of characters.—The above two examples illustrate some of the principles which guide the plant breeder but in practice they are not so simple. Instead of only two pairs of characters described as above, there may be three or four obvious differences and in some cases there may be some intangible features also like shattering of the grain. For obviously recognizable features there is no difficulty for multiplication, only the work will have to be done on a larger scale whereas, in the case of the non-recognisable characters there may be serious difficulties for multiplication.

In addition to glume colour and rice colour there may be a third pair of characters, round and long grain. If Tanjore *white sirumani* with white rice is crossed with a brown-glumed red-riced *kar* variety there is besides colour of glume and colour of rice, the shape of grain also. The round shape of *sirumani* being a simple dominant to long oval grain, the four F_2 types that occurred before, namely, straw red, straw white, brown red and brown white will each be represented by round and long grains. The three pairs of differentiating characters result in the production of eight types and these occur in the following proportion :—

Round straw red	27
Long straw red	9
Round straw white	9
Long straw white	3
Round brown red	9
Long brown red	3
Round brown white	3
Long brown white	1
	64

The type which is recessive in all the three characters occurs only once out of 64 individuals and unless the F_2 is twice or thrice as many as this we may not get this type at all. To obtain a stable form of round straw red at least 27 F_2 plants must be grown and probably certainly more.

Superposed on these eight distinct classes there may be characters not so readily discernable. For instance in the above cross the *kar* variety is a short duration (4 months) crop whereas *sirumani* is of six months' duration. If duration early or late behaves again as another simple pair of characters and earliness is dominant to lateness the above eight classes will be again subdivisible into sixteen. The recessive late growing long grain with brown glume and white rice would only occur on the average once amongst 256 individuals. A true breeding early plant with round grain, straw glume and red rice, the type showing all the four dominant characters would occur once amongst 81 individuals. To isolate it directly would require a very extensive series of F_3 cultures.

All the numerous features by which the multitude of forms of rice are distinguished are not inherited in the same way as some of the characters described above. One usually occurring feature is that the first hybrid (F_1) exhibits neither of the parent characters in its full intensity. There is a particular glume colour which looks green in the early stages and ripens into a light gold colour. This when crossed with the ordinary dark gold glume, the hybrid shows both green and gold, i.e., is intermediate in glume colour to the two parents with the gold appearing in patches. The grain of this when sown gives three groups of plants, two like the two parents and one intermediate between the two. The proportion in which these three groups occur is found to be 1 : 2 : 1, the two parental types being one each and the intermediate type two. When the F_3 types are sown again the two parental types breed true while the intermediate type gives all the three groups in the same proportion as the original cross did.

Modifications of ratios.—This mode of inheritance in which there is no marked dominance of one or the other of a character pair appears to be common. The closely packed arrangement of the grains in the ear-head is inherited in this manner. A cross between a bunched and a lax ear, gives an intermediate F_1 and the F_2 generation gives the three groups, equal proportions of the two parental types and double this of the intermediate type. This kind of inheritance which occurs with reference to several other characters in rice simplifies breeding work in that plants with the pure parental characters, can be picked out with certainty in the F_2 and there is no necessity to grow large F_3 cultures to isolate the true breeding types.

Another important feature in rice is that certain characters require the presence of two complementary units before they can develop. Two rices having either of these units and therefore not

showing the particular character, when crossed, show the character in the F_1 because the complementary units are brought together. When seeds of this F_1 are grown again we get plants showing the character and plants not showing the character in the proportion of 9 : 7. The 7 represent the three last terms of the 9 : 3 : 3 : 1 series resulting from the meeting of sex cells which do not make up the two complementary units. Further breeding will show that the 7 are made up of plants of different constitutions.

Yet another sort of inheritance may also be mentioned. Ordinarily a cross between red rice and white rice gives red rice in the F_1 which when bred from gives on an average 3 plants with red rice to 1 with white in F_2. But, there are different kinds of red. Sometimes, a cross between two red rices gives rise to plants in the F_2 generation with white rice. This occurs on the average once among 16 individuals. This shows that the red colour of the grain may be due to two separate units, some varieties having one and others the other. These white-riced plants coming from crosses between red-riced plants represent the last term of 9 : 3 : 3 : 1 series resulting from the meeting of sex cells carrying neither of the red-producing characters and they breed true to lack of redness in rice.

The above illustrations show that the plant is built up of a series of separate units like straw and brown glume, red and white rice, long and round grain, etc., each of which is capable of independent inheritance. On crossing forms of rice with different units, they segregate in the F_2 generation in all the possible combinations, two pairs of units giving four combinations, three eight, four sixteen, and so on. The whole process is very definite and the breeder can forecast what types will occur in the F_2 and also in what proportion they will occur. While some of the features have been shown to behave as unit characters showing independent segregation in the F_2 generation, the breeder should know whether the particular features he may be interested in, are also unit characters.

When it is now understood that new forms arise simply and solely from the regrouping of characters already present in the parents, any particular combination of results which the breeder requires is brought out by choosing the right types for crossing with each other. This naturally necessitates that the breeder should know what all characteristics exist in rice. He must have as it were a big collection of varieties, and should grow them pure and keep them under observation continuously. It is the maintenance of a large number of varieties that gives the breeder the material to choose from for his crosses. There is a large collection of rice varieties at Coimbatore, the number having exceeded 1,000. These different types probably represent all the possible variations and combinations of characters that would be possible in rice. The success or otherwise of breeding a desired type will depend upon the parents to be chosen for the crossing and upon the

parents carrying such characters as may be required. It will thus be apparent that a big collection of rice varieties is a desideratum for successfully evolving useful types by hybridization.

Qualitative and quantitative characters.—A distinction must be made at this stage between characters of the rice plant which are purely qualitative, morphological differences and which can be easily made out by eye judgment, and characters which are quantitative, i.e., which have to be measured. These may be the differences in length of grain, differences in the height of plants, differences in the number of ears per plant, differences in the size of the earhead, differences in the duration of the crop, etc. It is these quantitative characters which are of economic importance as they contribute to the yield of the plant which is the main consideration in breeding. To successfully breed out more economic forms we should know whether these quantitative characters are also inherited in the same simple way as some of the qualitative characters like colour of glumes. The study of the inheritance of these quantitative characters is not easy and requires complicated experiments. These quantitative characters are so much subject to the influences of the environment in which the plant grows that it becomes almost impossible in certain cases to separate the effect due to environment. Although hybridization has been practised for a number of years, the really useful forms evolved from such hybridizations are not many. This is entirely due to the insufficient knowledge we possess about the inheritance of these quantitative and economic characters.

When crosses are made between parents showing characters about the heredity of which little or nothing is known, it is assumed that these characters would also behave in the same simple way as those that were described before. While such assumption has generally been justified, exceptions have been met with which put a limitation to the production of new forms. Some examples of this experience may be mentioned.

Exceptions to simple Mendelian inheritance.—GEB. 24 is a valuable strain, grows well and produces a large number of earheads per plant but the earhead itself is an open lax one with comparatively few grains on it. In the varietal collections there was one type where the earhead was even smaller than GEB. 24, but the grains had the characteristic of being situated in clusters. It was considered that if a type could be bred by crossing the two with the salient characteristics of GEB. 24 and the clustered spikelets, the number of grains per earhead would be greater and hence the final yield would also be greater. When a cross was actually made the first hybrid showed an intermediate type of clustering of grains. When this F_1 was bred from, three types occurred, two like the two parents and one like the F_1 hybrid. The type with the clustered grain had only small heads like the parent. The clustering and non-clustering behaved as a simple

pair of alternating characters and there was no possibility of combining the clustering character with the greater earhead length of GEB. 24. The clustering is not inherited independent of the small length of the earhead.

Again GEB. 24 was crossed with a giant variety, growing over six feet in height and which had unusually long earheads but comparatively fewer heads per plant, the idea being to combine the greater tillering power of GEB. 24 with the longer earheads of this giant variety. Several generations were raised from this cross and the material gave valuable information about the inheritance of several important characters in rice. But so far as the panicle length was concerned, it was intermediate between the two parents in F_1 and in the variations observed in the subsequent generations wherever the earhead length showed an improvement, the number of earheads per plant was definitely less, so that what was gained in the ear size was lost in the ear number. The ideal of combining the ear number of GEB. 24 with the ear length of the giant variety was never attained. Moreover the types with a good ear length were too late in duration compared with GEB. 24 to be of any economic use. This cross shows that the good ear length is not inherited independent of poor tillering and lateness in duration.

There was still another cross made between GEB. 24 and another type in which the earhead had a bunched type of grain arrangement and consequently a larger number of grains per earhead. The size of the grain was also smaller than in GEB. 24. The F_1 was intermediate for the characters of the two parents and only three types of earheads were observed in the F_2 one like GEB. 24, one intermediate like the F_1 and the other like the other parent. The bunched type of head was always associated with smaller grains and there was another complication also in this cross. While the bunched type showed a small amount of unsetting, this was found to be considerably enhanced in the progenies of the crosses and almost all the bunched heads were bad with unsetting so that the possibility of getting a useful type with bunched heads and free from unsetting was very remote.

Modifications of Mendelian hypothesis.—Greater intensive work in rice as in several other crops has led to certain modifications of the original Mendelian hypothesis. These are (1) that the dominance is not always complete and (2) that the hereditary units controlling characters are not always independent. Certain units always tend to go together while certain others are always independent. There have been several examples in rice illustrating these points. Since the study of these various crosses, considerable knowledge has been gained about the inheritance and association of several economic, quantitative characters like duration, grain size, tillering, height of plant, etc., and the possibilities of evolving more useful types by hybridization are more hopeful. Whenever the association between an undesirable and

a useful character is not absolute there are distinct possibilities of growing a large population and getting at types which should prove slightly better than the parents. Crossing these slightly more useful types again either with the parents or among themselves have usually resulted in great improvement in other crops and this is being tried in rice as well. Studies on the development of the plant have given an insight into the plant characters which contribute to yield. Parents for hybridisation can now be chosen on the basis of these ascertained components of yield. What to look for in the progenies is now more definite and the work should prove more satisfactory.

The economic importance of the plant duration was mentioned previously. Inheritance studies have shown that earliness and lateness are contrasting characters, inherited either in a simple or in a complicated way according to the number and nature of units controlling this character, present in the parents. It is possible to get forms both earlier and later than the parents by crossing two parents of similar duration. It is also possible to get by crossing two types say of four months' and six months' duration, forms in the F_2 generation earlier than the early parent and later than the late parent. Duration appears to be one of the characters of the rice plant easiest to breed for. Duration is generally associated with yield within limits. Early duration varieties comparatively yield less than the late duration ones. It does not mean, however, that the very late ones say of over six months are really good yielders. Though such very late varieties may be grown here and there more to suit the conditions available in the tract, it may be safely said that most of the valuable economic varieties of rice grown in Madras are of a duration between five and six months. It was pointed out before that it would be possible to evolve strains by mere selection with duration shorter than the variety by a week to ten days. Though the possibilities of breeding a type, an ideal, of very early duration combined with a high yield do not appear to be hopeful, it appears to be quite possible to evolve types by hybridization between suitable varieties with durations of two to three weeks less than the parent without sacrificing yield.

One of the strains Adt. 8 evolved at Aduturai was derived from the variety Adt. 2 by crossing it with another similar variety. It is about a fortnight earlier than Adt. 2 and still has all the good characteristics of Adt. 2 including yield. In certain tracts it has been found to do even better than Adt. 2.

With the understanding of Mendel's principles of heredity it was hoped that it would be quite a simple matter to breed valuable economic types. This expectation had not materialised mainly due to the complexity of agricultural plant characters which are related to yield. A simple difference of red *versus* white rice

can be followed in its segregation. But no one has yet been able to identify and trace the segregation of the units which combine to make any agricultural plant character of great importance.

Limitations to breeding of improved types.—Agricultural plant characters which include yielding capacity are obscure complexes. Every one of them is understood to be the manifestation of a number of physico-chemical plant processes, these being identical with unit characters of Mendelian heredity. To synthesise ideal new types for various agricultural requirements would involve complete analysis of plant characters into ultimate units. Such a resolution is at present not conceivable. And even if it were conceivable it would not be of practical value. Crops have to be grown on widely varying soils and no two seasons are alike. Beyond a certain point, therefore, analysis need not go. There have been produced, no doubt, remarkably valuable types by breeding in certain other crops but the instances are comparatively few considering the possibilities visualised when Mendelism was first rediscovered. Except probably in sugarcane where the technique is much simpler, it being a vegetatively propagated crop, the value of the improved types evolved by breeding has been more in the way of attaining in them valuable ancillary characters rather than gross yield. Such ancillary characters may be improvements in the quality of grain obtained, better standing power of the straw, resistance to particular pathological diseases, resistance to intensive cold, frost, etc. A direct improvement in yield of say 10 to 15 per cent. would be all that might be expected from breeding by hybridisation. In Japan where breeding work in rice has been in progress much earlier than in any other country, it is authoritatively stated that about 20 to 25 per cent. improvement in yield would be all that might be expected by breeding, a 10 per cent. increase by mere selection and another 10 per cent. increase by hybridisation. If greater and phenomenal yields are being obtained there, they are due to improvements in agronomic practices.

In Madras a minimum of 10 per cent. increase in yield has been demonstrated by selection alone. Some of these selections have proved advantageous by possessing better quality rices. Some others like Adt. 3 (a mere selection) and Adt. 8 (a cross progeny) have proved advantageous by their special earliness. Other useful characteristics achieved besides yield are that some of them are non-shattering, some of them are tolerant to insect attack, and some can tolerate lateness in season, etc.

Breeding for characters other than yield.—Disease resistance is one of the useful ancillary characters often sought for by breeding. In Madras an important and popular variety of Tanjore, *korangusamba*, is at times subject to a serious attack of a fungus disease, *Piricularia oryzæ*. Observations had shown that strains GEB. 24 and Co. 4 were resistent to this disease. A programme of crossing work was therefore undertaken between *korangusamba* and the resistant strains. The cross between

GEB. 24 and *korangusamba* has gone up to the ninth generation and there have been obtained half a dozen strains which are as resistant as GEB. 24 and give an increased yield over *korangusamba.* Even when there is no disease present these strains have given an increase of 10–15 per cent. over *korangusamba,* which increase markedly becomes higher still (about 30–40 per cent.) when disease prevails. These strains have undergone yield tests in the tracts and the best of them will soon be available for distribution. This work has demonstrated the possibilities of breeding for disease resistance. Treatment of the crop in the field after the disease has broken out is not a practical proposition and breeding for resistance is usually one of the definite methods of attack by the breeder. The cross progenies of Co. 4 × *korangusamba* are still in the study stage and it is expected they might prove even more advantageous than the progenies of the first cross.

Straw character.—Another useful ancillary character often secured by breeding is the improvement in the standing power of the straw. Co. 3 is a simple strain evolved from a Coimbatore variety and has been observed to give a 10 to 15 per cent. increase in yield over the variety it was selected from. This has a tendency to lodge at harvest time and during adverse seasons the grains also shed. This has been crossed to one of the types in the collections with a stiffer straw and which does not shed so badly as Co. 3. Because of its comparatively poorer tillering, this type could not compare with Co. 3 in yield. One or two strains have been evolved from this cross which while possessing greater rigidity in the straw and greater freedom from shedding, are giving a definite increase in yield over Co. 3. They have satisfactorily finished the yield trials at the Coimbatore station and if they prove successful in the district trials, as they are expected to, they can replace Co. 3 which has already spread and thus materially add to the total outturn of the crop.

Crosses with wild rices.—The wild rices have all the undesirable characters in them, viz., their prostrate habit of the stem, the easy shedding nature of the grain, the possession of long awns on the grains, slow and defective germination, etc., the only relieving features about them being their resistance to drought conditions and greater freedom from plant diseases. Crossing between wild and cultivated types has been done at Coimbatore and it would appear possible to evolve types having the drought resistant character of the wild rice but without its undesirable characteristics.

Time taken to evolve a strain by hybridization.—The technique of crossing in rice has already been described. The process of evolving improved strains from the cross progenies is not simple and requires sound knowledge of the heredity of some of the useful characters we are after. The yield trials adopted in ordinary selections are also necessary in the case of strains from crosses

but only they come at a later stage. The first few generations of the cross are all impure for one or more of the hereditary characters. All the difficulties experienced when undertaking simple selection also appear with regard to selection from the hybrid progenies with the additional difficulty of getting a true breeding type. The progenies must be grown on for several years keeping those from individual F_2 plants separate in the succeeding generations. It is not wise to start selection work at too early a stage. Experienced eye-judgment and records of development must progressively weed out the less desirable ones as otherwise the material will get too unwieldy to handle. By F_9 or F_{10} we may get a few families pure for all the more important unit characters, and satisfactory for yield or quality by small scale trials. The breeder has to finally discriminate and choose the best of these by large-scale trials as in simple selections. The time thus taken to evolve a strain from the cross progenies is much longer than in the case of ordinary selection. Ten years will be the minimum period by which any strain can be expected to be placed in the hands of the cultivator.

The proportion of plants impure in one or more characters decreases throughout the generations from the F_2 onwards. It might be asked why should selection be attempted at such a stage and why not allow the progenies to come to a pure stage for the characters. The selection can be done at a later stage when the chances of their being pure are very great. This method known as 'Svalof method' which was first tried in Svalof in Sweden can be tried when there are other more pressing problems for the breeder to engage himself with. This method is also being tried in rice and it is too soon to speak of its merits or demerits.

The technique of the series of operations involved in the ordinary selection was described before. The same technique applies to the studies of the cross progenies also. Great care is needed at every stage of the work. The cross seeds are usually first sown in separate pots along with the parents and then transplanted in the field. Though self-fertilization is the rule, natural crossing can take place and to be absolutely sure, it would be safer to self a few plants in the F_1 stage. Selfing consists in enclosing the whole plant within a cloth bag to prevent any foreign pollen getting access to it. It will always be a useful plan to grow a few lines of the two parents of the cross at every stage along with the selections for rough comparison of the characters.

CHAPTER XXII

Cytology

Chromosome theory of heredity.—The study of cytology, i.e., the changes in the cell contents, has made rapid advances during the last three decades and has contributed much to the study of the inheritance of characters. Every living thing, animal or plant, is made up of cells. These are minute bodies varying in size, shape and function in different parts of the organism. In every cell is a nucleus on which the life and activity of the cell depend. The nucleus while small even in comparison with the cell, has yet smaller bodies inside it. These are the chromosomes, dark staining, minute bodies. It was twenty-five years ago that a definite connection was actually established between the behaviour of chromosomes and the laws of heredity. The actual Mendelian units are found to be situated in these chromosomes. It is to Professor Morgan of America and his associates that we are indebted for the present chromosome theory of heredity. The chromosomes can be seen only under the microscope and can be counted. Their size varies with different species of plants, they being generally larger in liliaceous plants. In rice they are particularly small, looking like pin heads even at a magnification of 2,000 times.

The number of chromosomes of a species is important because it is constant and different for each species. In the ordinary cell these chromosomes remain in pairs. When the plant is entering the reproductive stage, i.e., forming the sex cells the partners of each chromosome pair get separated and one goes to each of the sex cells either male (pollen) or female (egg). When two sex cells meet again in fertilization the full complement is restored and the chromosome pairs go on dividing and enter into the nucleus of every cell as it is being formed.

According to the chromosome theory of heredity all the known hereditary units for characters must form as many groups as the number of chromosome pairs in the species. The units located in each chromosome always tend to remain together and the characters responsible are then said to be linked. But occasionally during cell division when the sex cells are formed, portions of the pair of chromosomes get interchanged and the hereditary units located in such separated parts also get separated and this is the phenomenon known as crossing over. The hereditary units are supposed to be arranged in a linear fashion just like a string of beads along the length of each chromosome and the closer together these units are situated, the less are the chances of their getting separated.

In the fruit fly *Drosophila*, which has been the object of great, intensive studies, there are only four chromosomes and with the large number of hereditary characters whose inheritance is known

in this fly, they have been able to even map out each of these chromosomes showing the different hereditary units each of the chromosomes contain and even the probable distances between these units. In plants, maize and sweet peas are the only two where such intensive studies have been made showing the units contained in each of the chromosomes. As new characters come to light and their inheritance becomes known, their location in particular chromosomes and their relation to other units in the same chromosome are determined.

Rice contains twelve pairs of chromosomes and all the hereditary units must therefore fall into twelve linkage groups. Compared to maize and sweet peas the number of characters whose inheritance has been studied in rice is comparatively fewer. These characters include purely morphological characters as colour of glumes, colour in the several parts of the plant, presence or absence of awn, etc., and economic characters like duration, size of the grain, shattering of the grain, etc. The inheritance of some of the characters is simple in certain cases and complicated in others according to the number of Mendelian units responsible for their expression. Over 100 units have been recognized in Coimbatore studies and the attempt is now directed to find out the groups into which they fall. One or two of these groups have already been identified but the interactions among the several units constituting a group remain to be investigated.

Association of characters.—While the simple morphological characters like presence or absence of pigment in the different parts of the plant may, by themselves, be not important it is possible that some of them may belong to the same group having other valuable economic characters. While the grain size may behave independently of other characters there was one instance where there was a complete association between grain size and shape and its fineness or coarseness. The depth of gold colour on the glumes was varying from dark to a very light intensity. It was found that the dark gold had broad and coarse grain whereas the light gold had grains thin and fine. Valuable associations among quantitative characters have also come to light. In several crosses it was found that the height of plant and duration went absolutely together, all the early plants being short and all the late plants being tall.

In certain crosses the amount of unsetting in the individual progenies is found associated with particular grain size and its arrangement in the panicle. Then again there is found an association between straw character and amount of unsetting. The identification of such associations will prove of considerable advantage in breeding work. In breeding work for agricultural plant characters it is difficult to find out exactly how many Mendelian units control a particular character and even if this is determined it is not of much help. It is the association or relationship between one agricultural character and another that is really important and of

use in breeding. Observations on pure lines for a number of seasons reveal that tillering, panicle length, height and duration are all related to yield.

Though the presence or absence of pigment in any particular portion of the plant like internode, leaf, glume, stigma, etc., may behave as simple Mendelian characters there is one group in which a large number of the units responsible for the development of pigment appears together. It would appear that all the units responsible for pigment in different parts fall in two linkage groups. Though the identification of the groups and the inter-relationship among the units of each group can never be expected to reach the stage which has been reached in the Drosophila fly or in the maize plant, work is definitely, though slowly progressing.

Cytology and sterility.—It was shown how the linkage among different Mendelian units responsible for different characters by being located in one chromosome sets up limitations to the breeding of any and every type of plant we may be after. Apart from linkages we come across the problem of sterility in the hybrids about which mention was made before. The chief manifestation of such sterility is the occurrence of ill developed or non-viable pollen or male sex-cells. The study of cytology has been of great help in understanding the cause of these irregularities. Such study is able to connect the occurrence of sterility with particular behaviour of the chromosomes. It was observed that the number of chromosomes was constant for each species. When species of different chromosome numbers are crossed, in the formation of sex cells some of the chromosomes go unpaired and the sex cells which contain these unpaired chromosomes are non-viable. This is the case in wheat where there are three races, having 7, 14 and 21 chromosome pairs respectively. From efforts made at crossing various races, it has been found that two wheats having the same chromosome number will inter-cross without sterility. If two wheats differing in chromosome number say one with 14 pairs and the other with 21 pairs are crossed, the resulting hybrid (F_1 plant) is partially sterile and in its progeny will be some plants fully sterile, some partly fertile, and some fully fertile. This sterility caused by different chromosome numbers is different from the sterility which is caused by Mendelian units.

The determination of the number of chromosomes and intensive studies on their morphology and behaviour in hybrids have led to an understanding of the evolution of the cultivated types. For instance in wheat as in other plants, the plant with the least number of chromosomes is a primitive form and the plant with larger numbers has been derived from the primitive form by chromosome duplications either by crossing or by mutations. In rice, however, the real primitive forms probably do not exist. Almost all the species of *Oryza* including the wild ones contain only twelve pairs of chromosomes.

Apart from differences in chromosome numbers, sterility may also be caused in crosses between plants having the same number. Some rices when crossed produce a very large amount of sterility. It was pointed out that the units responsible for the plant characters are in the chromosomes. By the growing of plants for centuries and centuries these units undergo small changes and the varieties of rice growing under one set of geographical and climatic conditions attain a particular stable composition or arrangement of the units in their chromosomes. This composition or arrangement may be different for rices of different regions. When rices belonging to two such regions are crossed, due to the differences in the composition of chromosomes certain irregularities occur in the union and separation of sex cells and these cause unsetting or sterility.

Differences in chromosome numbers.—Cytological studies in rice at Coimbatore have led to the identification of several irregularities in the chromosome numbers and such irregularities have a bearing not only on setting but also on the stature of the plant. Sometimes instead of the normal (12 pairs) 24 chromosomes, plants may result with 12, 36 or 48 chromosomes. The plant with twelve is very diminutive with all the parts of the plant reduced and is completely sterile, i.e., it cannot produce seeds. Similarly the plants with 36 and 48 chromosomes are comparatively bigger and better developed than those with the normal 24. In fact the chromosome numbers are related to the size and vigour of the plant in rice as in one or two other recorded cases.

The knowledge that the increase in the number of chromosomes goes with increase in the size of the plant has been made use of in certain other plants to produce artificially, duplication of the chromosome sets so that the plant arising from such duplicated sex cells may be bigger and more productive. This doubling in an otherwise sterile hybrid (F_1) between two species having different chromosome numbers, may give fertile off-spring as the partnerless chromosomes now get their partners. A number of such plants with duplicated chromosome sets have been secured both naturally and by artificial means from the sterile F_1 in the inter-generic wheat-rye cross, in maize, in Solanum, in cabbage X radish cross, and in several wild or ornamental plants. These plants which arise by the doubling of the chromosomes are so different from the originals that they are usually put into a different species or even genera. All the plants with the different chromosome numbers are being studied in rice.

After repeated failures, crosses have been successfully made even between different species of rice, i.e., *O. sativa X O. latifolia* and *O. sativa X O. longistaminata*. The F_1s were sterile but when back crossed to *sativa* parent again gave some seeds. The inter-species and inter-generic crosses have led to phenomenal results in Russia and other countries, and it is likely that the Coimbatore work may lead to similar results, apart from their academic importance.

Mutations.—Besides changes in whole chromosome numbers there may be changes in the Mendelian units located in the chromosomes or in portions of chromosomes. These are called mutations and these mutations do occur in nature though rarely. It has been demonstrated however, that mutations can be artificially induced by subjecting the material, seed, plant, pollen, etc., to X-rays. In this way new unit characters, as contrasted with new combinations of existing characters, produced by hybridisation, may be placed at our disposal. Rice subjected to X-rays at Coimbatore has produced a large number of mutations, some of them entirely new, and some which have already been observed in nature. That X-rays bring about changes in chromosomes is evident from the large amount of unsetting caused in plants from X-rayed seed. Most of the mutations obtained so far have been on the negative side only, i.e., they do not show any valuable characteristic not present before, but the work, from the analogy of results obtained in other plants, is full of possibilities.

CHAPTER XXIII

Resume of the Yield Problem

The yield of the crop whose improvement is the main objective of all departmental activities, is controlled by a great number of factors. They can be broadly grouped under (1) soil, (2) climate, (3) agricultural and manurial practices, (4) pests and diseases and (5) botanical forms and varieties.

As regards soil, the inherent differences are reflected by the large variation in acre yields obtained in different parts of the world. If we take up the world statistics and examine the acre yields it is found that they vary from 500 lb. to 5,000 lb. In Japan recently, in a competition for a special prize offered, an acre yield of over 7,000 lb. of grain has been recorded. The averages are over 3,000 lb. for countries like Spain, Italy and Japan while the average is about 1,600 lb. for Madras and only 1,000 lb. for the whole of India. In countries which record high yields, apart from higher general fertility of the soil, artificial fertilizers are used in large quantities. In Spain and Japan, they apply 60 to 80 lb. of nitrogen and 50 to 60 lb. of phosphoric acid per acre in the shape of fertilizers. They easily spend more than Rs. 50 per acre for fertilizers alone. The soils of Japan already contain about ten times the quantity of available nitrogen and phosphoric acid found in the South Indian soils and over that large quantities of fertilizers are applied. Under the present economic condition of the South Indian rice cultivator, it will be too much to expect of him to spend more than Rs. 10 to Rs. 15 per acre towards manures.

In Madras the highest average yields are obtained in the Godavari delta and the lowest in Malabar and Ganjam districts. The poor yields are due to natural deficiencies and any scheme of improvement must first consist of improving such deficiencies in soil by suitable manuring. Of the several manures, the advantage of green manuring is evident throughout the Province and appears to be the cheapest method of improving the fertility of the soil. In addition to green manures, applications of phosphates like super. or bone meal appear to give satisfactory results where the phosphate deficiency of the soils is pronounced. While the applications of chemical fertilizers by themselves have not proved advantageous or economical, small quantities of them in conjunction with green manuring or bulky organic manures offer the best scope. Though the present prices of produce are against the application of fertilizers on any large scale, small quantities of ammonium sulphate or ammonium phosphate to

soils where any particular deficiency is most pronounced may prove advantageous. The results of the various manurial experiments have been discussed to prove that this is so. Experiments at Maruter have definitely proved that improved strains respond better to intensive manurial treatment than the ryots' unselected seed.

Climate is a factor we have no control over. Some varieties of rice appear to be peculiarly adapted to certain conditions of climate. The so-called most prolific varieties of the sub-temperate climates (from Spain, Italy and Japan) have proved failures under our tropical conditions. It would appear, therefore, that the best way of meeting the situation will be to carry out systematic trials of the available prolific varieties of the province and decide upon the most suitable for each locality or tract. It is possible that crossing between varieties of different geographical races, though beset with difficulties on account of unsetting, might prove advantageous. This line of investigation which is receiving attention in Coimbatore is full of promise.

As regards diseases, any curative treatment for an extensively cultivated crop like rice, does not hold promise and the problem is mainly one of breeding resistant varieties by making use of a certain amount of natural resistance displayed by varieties. That useful results may be expected of this line of work has been proved by the breeding programme adopted to evolve *piricularia* resistant forms. Regarding insect pests, while some may offer scope for the adoption of preventive methods, the main line of attack should consist in the search for particular varieties of rice tolerant to insect attack and in the adjustment of growing practices taking advantage of the non-harmful period of the insect attacking the crop.

The influence of agricultural practices like broadcasting and transplanting, methods of raising seed-bed, spacing to be given between plants at planting, age of seedlings to be planted, manuring of the seed-beds, manuring of the transplant field, etc., on yield have all been dealt with. The modification of the above to get the best results would appear to vary according to the tract and the variety. There are several tracts even in our own province where the improvement of cultural practices alone can increase the present yield by 20 to 25 per cent., and this combined with the growing of improved strains should still enhance the acre yields. At the Central Farm, Coimbatore, the average acre yield which was about 2,000 lb. some 15 years back has now been brought up to nearly 4,000 lb. by the adoption of improved cultural and manurial practices combined with growing of strains. Though it may not be possible to raise the yields to this high level throughout the province, there is no doubt that conditions exist in certain parts, where intensive methods adopted in Coimbatore could be followed and yields raised to the level of Spain or Italy.

Under varieties and botanical forms comes the work of the breeder. His work consists of three stages (1) comparison of the existing varieties and determining the best variety for the locality; (2) obtaining pure lines by simple selection from the best of the local varieties that would give a higher yield than the unselected crop, and (3) obtaining selections from crosses deliberately made that show a combination of the useful characters that may be present in one or more varieties. A large amount of improvement has been effected so far as the first two lines of work are concerned.

Success in breeding out new types requires an understanding of the association existing among the number of Mendelian characters in rice because, some associations limit the possibilities of obtaining any and every combination of characters we may desire to have. While the inheritance of most of the morphological characters is simple and controlled by one or two units, the quantitative characters that contribute to yield are governed by multiple units and their effect is also masked by environmental conditions. While a certain amount of improvement in yield may be expected by the evolution of strains from hybrid progenies, greater scope appears to lie in the improvement of ancillary characters which indirectly help yield. These may be, breeding for disease resistance, breeding for non-lodging of the straw, breeding for the non-shattering character of the grain, breeding for better quality rices, etc. Though a good deal of work yet remains to be done, the results already obtained have shown the enormous possibilities in these lines of work.

The possibilities that have been demonstrated of utilizing the latest developments in cytological knowledge in other advanced countries have been realized and work of a similar nature is in progress in rice also. These consist of crosses between geographical races, interspecies crosses, inducing mutations by artificial means, etc.

The importance of undertaking developmental studies has been emphasized. It is such studies that give an idea as to what contributes to yield and how yield differences are brought about. The outstanding characters of the rice plant which contribute to yield are, (1) tillering or number of earheads per plant, (2) number of grains per ear, and (3) weight of the individual grain. The relationship of each of these factors to yield and the influence of environmental conditions as spacing, manuring, age of seedling, etc., on them have been studied and understood. A correct understanding of these influences gives greater scope for designing crosses and for making selections from progenies of such crosses.

Thus the problem of yield improvement, has to be attacked from a wide front to get the most satisfactory results. Though single plant selections by themselves combined with better cultivation practices have brought about great improvements already,

still greater improvements are possible only by the breeding of special varieties or strains from crosses. These strains with a proper adjustment of cultural and manurial practices for improving yield attributes, will result in the greatest benefit.

An idea of the improvement already effected by the evolution of strains can be had from the following figures. During the 1933–34 season the total area under the improved strains in the province has been estimated to be at least eight lakhs of acres. Taking the average acre yield at a very modest figure of 1,500 lb. per acre, an improvement of ten per cent. in yield by the growing of strains would amount to 150 lb. of grain which in money value at the present price is equivalent to Rs. 4. Thus the value of the improvement over the whole area comes to 32 lakhs of rupees. Improved seed enough to sow about 2½ lakhs of acres has been distributed during the year 1934–35.

CHAPTER XXIV

Pests and Diseases

Insect pests of rice

In the Madras Presidency more than thirty different species of insects are known to attack rice. Fortunately, however, several of them occur only occasionally or in such small numbers as to be of little more than academic interest. The really serious pests are not many, but when they do appear, they appear in such numbers that their attacks prove disastrous.

Some of the pests attack the young crop, especially when it is in the nursery stage. Of these the most important is the Army worm of rice (*Spodoptera mauritia*). It appears all on a sudden in thousands and tens of thousands and wipes out whole areas. The other pests of nurseries are the black spined beetle, the rice hispa found throughout the Presidency and the blue-black beetle (*Leptispa*) peculiar to Malabar, both of which are capable of seriously damaging a young crop. Sometimes thrips attack young seedlings and suck up the plant juice and affect the vigour and growth of seedlings.

Of the pests that attack the crop after it is transplanted the most important are the rice gall fly and rice mealy bug. When the plants are forming ears it is subject to the stem-borer (*Schenobious incertellus*) and to the rice bug (*Leptocorisa acuta*).

To combat any pest effectively, its life history and habit must first be known, and a general knowledge of the weak points of its life-cycle gained so that the control measures might be devised accordingly. The successful application of the measures again may demand a full knowledge of the conditions under which the pest occurs, so as to modify them, where necessary to suit particular conditions. There are, however, various difficulties in adopting control measures. Sometimes after once appearing, the pest may not appear again in the tract for some time. The rice crop being grown on a very extensive scale, when wide spread attacks of pests are noticed, it would prove a sheer impossibility to adopt any control measures.

The Army worm of rice (Spodoptera mauritia).—This is one of the worst pests on rice. This is an insect (caterpillar) which appears all of a sudden in enormous numbers on nurseries or on young broadcast crop. The cultivator usually notices its presence only when the crop has already been partly devastated and very soon the pest disappears after doing the havoc. The caterpillar defoliates seedlings and young plants. The caterpillar is of nocturnal habit. During the day it hides under clods and crevices

of the soil or rests on the soil surface, and begins to feed at night-fall. Whole fields are sometimes wiped out in a single night. After destroying one field the caterpillars march over to the next in large bodies. Though it occurs chiefly in Malabar it has been noticed also in Northern Circars and Tinnevelly.

Remedies against this consist in flooding the infested fields or nurseries where water is available. When the caterpillar is very young sweeping with hand nets may also be adopted. Sometimes digging a deep trench round the nurseries prevents the caterpillar migrating to the next field. Cutting down grasses on the bunds where eggs are usually laid in the off-season may also be adopted; scraping the bunds and exposing the pupae may keep the pest under check.

Rice Stem-borer (Schenobious incertellus).—This is another major pest on rice. It occurs in most tracts and is particularly bad in Northern Circars. The caterpillar bores into the stem and kills the shoot and causes the characteristic white-ears. Though counts of such ears taken in the field have shown that the damage is only from one to three per cent., in certain seasons, the infestation leaps up to ten to twenty-five per cent. or more at times. It attacks also seedlings in the nurseries and sometimes kills them. When the attack is in young transplanted seedlings, tillering is very much affected and the plant is not able to make any headway. Studies on the stem-borer carried on at the Maruter station for a number of years show that its effect on the rice crop in the delta is largely manifested from the end of October to early February, so that the first *sarva* crop is affected when it is in ears and the pest goes next to the nurseries of the second *dalwa* crop sown in December-January. The relationship of this pest attack to the second crop in Godavari has already been mentioned. The ryot has evolved suitable methods to evade the attack of stem-borer. Knowing that the broods emerge and attack the crop between September to January, he goes in for a short duration variety for the first crop which will finish flowering by September and delays the planting of the second crop until February.

Comparative observations on the incidence of the pest on different varieties of rice grown at the same time on this station showed that the incidence varied with varieties and it was definitely less in GEB. 24, than in other varieties.

The stem-borer moth is easily attracted by lights. Counts of catches (males and females) have been made at different rice stations in different parts of the year and from the observations so far made it may be said that (1) at every fresh brood the insect comes to light in very large numbers, (2) that at the peak of emergence it is highly phototropic and comes to light at all hours of the night even in moonlight nights, (3) the percentage of the gravid females (those with eggs) is always greater than the spent ones, (4) the proportion of females to males varies in different localities

and in the same locality during seasons and (5) during the rice season the insect makes its first appearance in the trap during transplantation.

Use of light traps and preventing the moths laying eggs on the crop appear to be the possible remedies against this. In the seed-beds the egg masses can be easily identified, collected and destroyed. If this is done, the transplanted crop can be saved from the attack. It has been found in other countries where the stem-borer is a pest that flooding the fields and allowing the water to stand and rise in temperature slightly, 25 to 30°C., kills the larvae.

Rice Hispa (*Hispa armigera*).—This is a small bluish spiny beetle often found bad in South Kanara. It has also been noted in Salem, and Chingleput districts and in Northern Circars. Here both the grub and the beetle do damage to the young crop, the former by mining into the leaf tissues and the latter by scraping the green foliage. It attacks seedlings as well as a broadcast crop. Badly infested fields present a whitish, dried up foliage. It is generally found in the summer crop grown in isolated patches in South Kanara and Malabar. Sometimes the whole crop may be lost. Later it goes to the main crop sown in June and because of the extensive area the damage may not be very perceptible. It appears later in the seed-beds of second crops and continues on.

If the attack is in the nursery the pest can be controlled by flooding the field, forming a thin film of kerosene emulsion on the top and passing a rope across the field. Hand netting to catch the beetles is found very effective and practicable. At each sweep of the net hundreds of insects may be caught when the attack is serious. When transplanting, the tips of the seedlings may be clipped off and destroyed. When the attack is in the large fields directly sown, the control is rather difficult. The appearance of this pest in large numbers is a serious limitation to the success of the second crop in South Kanara. Sometimes when the season is bad, without timely showers, the vigour of the plants may be so seriously affected that the whole crop may be lost. The best time to take control measures would appear to be the summer crop season and later the seed-bed stages of the main first crop.

Rice plant requires warmth at the time of tillering. The second crop planted in cold weather does not get this necessary warmth so much so that the tillering is not vigorous. If the insect attack also synchronizes with this stage, the plant is very much affected. This may be the reason for the serious consequences of the attack by the hispa and the stem-borer in the second crop.

Rice Bug (*Leptocorisa acuta*).—This is present in almost all rice tracts and is characterised by its bad smell. It is found also attacking ragi, cumbu, and other grasses now and then. This is not a serious pest of rice.

The bug sucks the juice from the tender ears with the result that the grains remain discoloured and half filled. It appears almost every year at Coimbatore, when the early varieties start flowering. Hand-netting has been found to be very efficacious. Removal of the grasses from the bunds where the bug breeds may also give some relief.

Rice Grasshopper (*Hieroglyphus banian*).—This is also not a serious pest of rice though found occasionally in the West Coast, Mysore, Northern Circars, Tinnevelly and Chingleput. In parts of Ganjam this has been found to be a serious pest, particularly on broadcast crops. The grasshopper does damage by feeding on the foliage and by cutting the earheads.

Use of hand nets and bags on the field bunds soon after the early rains when the eggs hatch out into hoppers has been tried with success. In Ganjam scraping and digging up the field bunds in summer and exposing the egg masses has been tried and found to be practicable. The control measure to be really effective has, however, to be adopted by all the people co-operatively in a tract as otherwise the advantages would not be apparent.

Rice Gall Fly (*Pachydiplosis oryzae*).—This disease is called *anaikombu* in Tamil and *kodu* in Telugu. This occurs in several places and occasionally as a serious pest in certain tracts under certain conditions. The main symptom of the disease is the production of a hollow tube-like outgrowth from the centre of the shoot in place of the normally developed internodes and leaves. This outgrowth is called the silver shoot. In a case of light attack, in spite of the appearance of silver shoot in the main stem, tillers are produced which bear normal earheads, but in instances of serious infestation almost all the side shoots that may be produced by the plant may be successively attacked so that no earheads are produced.

The silver shoot is the shoot gall caused by the maggot of the small gall-fly, which bores into the stem attacking the shoot bud. Rice is susceptible to the attacks of this pest during the first three months of its existence, and during this period there may be as many as four generations of the pest following one after another in quick succession.

This pest is kept effectively under check by several parasites as they usually make their appearance at the very outset of the attack along with the pest. It would appear that the outbreak of the pest would occur only when the development of the parasite is retarded by some abnormal external factors. There appear to be certain grasses which serve as alternate hosts for the pest when there is no rice crop. It is said that an abnormally wet weather and lateness in planting are favourable factors for bringing about a heavy infestation.

There is no definite remedy for this pest. Probably a quick acting fertilizer if applied at the initial stages of attack may help the plant to tiller freely and get over the trouble.

Paddy Mealy Bug (*Ripersia oryzae*).—The disease is known as *soorai* in Tamil and is sometimes bad in Tanjore, Trichinoply and South Arcot districts. It also appears in Godavari and Kistna and is called *dumpa tegulu* in Telugu. Colonies of this minute insect infest the inside of rice leaf sheath and suck up the plant sap with the result that the affected plants remain stunted. The attack becomes apparent only when other plants grow up at the time of producing earheads. Such affected plants appear in patches here and there in a field and do not produce any earheads. In severe attacks the whole plants present a scorched up appearance and if the plants are examined, whitish remains of the bug can be seen inside the leaf sheaths. How the attack appears in patches is not definitely known. Observations made at Maruteru have shown that the initial infection takes place in the seed-bed and wherever such infested seedlings are planted, the insect multiplies and spreads to the neighbouring plants. The insects when they drop in water can remain afloat on bits of straw and get distributed to healthy plants. How the insect passes through the off-season when there is no rice crop is not sufficiently understood.

No effective remedy is known against this pest. As a preventive measure the plants as soon as they show the attack may be removed and destroyed and this has been found to be effective in stopping the spread of the pest.

Rice thrips (*Thrips oryzae*).—The insect appears in seed-beds particularly when the sowing is done late and the plants do not get the advantage of the seasonal rains. It appears in the seed-beds almost every year at Coimbatore. When in large numbers they suck up the plant juice, and the tender leaf blades get rolled up and present a withered appearance. In a very severe attack the seed-bed may be destroyed. The general effect of the attack by thrips is that seedlings remain thin and the seedlings are not found sufficient to plant the programmed area. There appears to exist a certain amount of difference in the susceptibility to this pest among rice varieties grown under identical conditions.

The pest is easily controlled by flooding the seed-beds with a thin film of kerosene emulsion on the top. If water is not available, spraying with a dilute infusion of tobacco is also found to be very effective and economical. Subsequent to the flooding or spraying, a small dose of ammonium sulphate applied to the seed-bed makes the seedlings grow vigorous and get over the trouble.

Among the pests of rice besides insects the following may have to be taken into consideration. One is the crab and the other the **rat.**

Non-insect pests

Crab.—Crabs do damage to the rice crop both directly and indirectly. The indirect damage arises by the crabs making holes through the bunds and causing the water to drain away from the fields which is a serious point in times of water scarcity. The direct damage consists in the crabs nibbling the sprouting seedlings in the nurseries and also cutting through freshly transplanted seedlings. A crab-damaged field can be made out from the large number of gaps that occur and the cut portions of the young seedlings floating in the water. If fields can be watered and drained completely until the plants have all established themselves there is no risk of any crab damage but such a perfect draining is not possible because there will always be pockets where water stagnates. Often the damage is very severe in fields not satisfactorily levelled and it is confined to the portions where water stagnates. Often in experimental fields where seedlings are planted in singles and with regular spacings the damage by crabs becomes very serious and makes the results unreliable. Though the cutting of the plant by the crab is done at just below the water-level, the stubbles can shoot up if it is an already established plant.

Control measures.—Control measures consist of both keeping the fields well-drained and destroying the crabs either by catching them or trapping them. Just at the commencement of the season when water is first let into the fields, the big crabs that remain inside deep holes come out. Small boys and girls employed at this time are able to catch hundreds of crabs. Some of these are gravid females about to liberate the 300 or 400 young ones which they carry in their abdominal flap. Catching them at this time certainly helps in keeping the crab population down within limits.

Trapping the crabs has also been tried with success at the Aduturai station. The trap consists of an ordinary wide mouthed mud pot buried in the corners of the fields with its mouth in flush with the level of the field. The pot is baited with two handfuls of rice bran which can be renewed every alternate day. The smell of the bran attracts the crabs which drop into the pot and are held captives there, the sloping convex neck of the pot preventing all means of escape. The crabs caught in the trap are removed daily and destroyed. The dead crabs put into a pit and covered over with earth, rot and form useful manure. Usually five to six traps may be sufficient for an acre.

The two methods, catching and trapping have been compared and though trapping may be cheaper, the catching is probably more efficient. It is in the catching that a large number of gravid females along with their young ones get destroyed. Catching is done by young girls and boys who are too young to do any other work in the fields and they are paid not more than two annas a day. After the planting is over, women coolies who

have no other work, can also be employed. Trapping may be employed with advantage where juvenile labour is either not available or is expensive.

Besides traps a trial with poisons was also conducted at this station. Calcium cyanide, a small quantity of it dropped into each crab hole and closed with wet mud proved effective in killing the crabs but the method involved considerable waste of time and was also very expensive. There was also the risk in letting the coolies handle a dangerous poison.

At the breeding stations in portions where the most valuable families are planted, coolies are employed as soon as the planting is over to catch crabs whether they actually do the damage or not, just as a sort of precaution. The damage to transplanted crop occurs soon after planting, and when once the seedlings are well-established and begin to produce tillers there is no risk of damage by crabs.

Rats.—This is another serious pest on rice. It attacks both the growing crops and the harvested and stored rice. The rat does damage to the field crops principally when the earheads are forming and the damage is often attributed wrongly to the rat-snake which goes after the rat. The cultivator by often killing the snake is removing one of the important biological methods of control over the rat population. Sometimes the young growing plant is also attacked and one can see in the burrows plenty of the tender shoots of rice plants. The rats that do damage to rice crop in the field are probably semi-aquatic and they live and breed in the field bunds. They are found to jump into the water, swim and escape when burrows are disturbed. They have tortuous burrows with a number of exits. While the burrows can be easily made out by the piling of the fresh earth at the openings when the crop has been harvested, it is rather difficult to make them out when the crop is growing and there is water in the fields.

The usual control method adopted consists in engaging professional rat-catchers who dig out the burrows and kill the rats. These men easily locate the burrows and rat-runs and dig down from the top with a pointed stick and the moment they see a rat they strike it with the stick and kill it. It is very rarely that a rat once located escapes their hands. These men are usually paid at so much per rat caught and there is no doubt that such catching tends to alleviate the rat nuisance. There is, however, one difficulty with regard to the catching, namely, the bunds have to be repaired and set right again after they have been dug up for catching the rats.

The cyanogas foot-pump by which calcium cyanide dust is blown into the rat burrow was also tried against rats at Aduturai. While it did kill the rats wherever they were found inside, the use of the pump by itself was not helpful in completely stopping

the rat nuisance. During the rice-growing season, the burrows are not easily made out and during the off season when the crop is off the fields, the bunds crack and it is impossible to make the holes air-tight, when only fumigation could be effective.

Poison baits are also tried in some cases but they cannot be said to be a great success under field conditions. Digging the bunds and destroying the rats though comparatively more expensive than other methods is certainly the most efficient.

Birds.—Birds, particularly sparrows, sometimes do considerable damage to ripening crops in fields. Usually crops grown out of the season or very early rices that come to flower much in advance of others are subject to bird attack. The only way to meet the difficulty is to scare away the birds by cooly boys or by means of any rattling device.

Pests on stored grain

Rice weevil (*Calandra oryzae*).—This attacks both milled rice and unshelled grain. The larvae easily make their way through the husk. As the eggs are laid inside the grain first, the grub feeds on the kernel and after attaining maturity comes out of the grain. The damage due to this insect is particularly serious in the finished rice ready for human consumption. The presence of the weevil in white milled rice is accentuated by the close proximity of lower grade broken rice and rice bran and therefore these should be stored away from the milled rice.

The red-flour beetle (*Tribolium castaneum*) is a common pest attacking several stored grains including rice. The elongate white larvae are found in the infested material.

The rice moth (*Sitotroga cerealella*).—This is a small shining insect found flying in numbers inside infested granaries and causing damage to stored rice in husk. It is the caterpillar of the moth that bores into the grain and turns it into chaff. There appear to be varietal differences with regard to the attack by this pest. Glutinous rices and rices with golden brown glumes appear comparatively to be more susceptible than others.

Control.—The above insects breed and multiply so rapidly that all the different stages are found on the same material, and once infested, the material is greatly damaged in a very short time. The pests also get dispersed when infested material is conveyed from place to place. The effective measures for controlling these insects are thorough cleanliness and proper drying and cleaning of the material before storage. The material must also be examined periodically and dried again if the storing period is long.

Even after general cleaning of all the receptacles used for storing and keeping them closed, the infection may come in as there may be minute eggs or larvae which might escape notice during

cleaning and drying and get multiplied in course of time. Fumiga tion of the store-houses or receptacles with carbon-bi-sulphide has been found to be very effective. The usual dose is one ounce of the liquid to every 15 cubic feet of space enclosed and the period allowed is 24 hours. Since carbon-bi-sulphide is an inflammable material precautions must be taken not to take any fire or naked light near the fumigated chamber for some time.

As a preventive measure against the rice moth, a thin layer of dry sand may be kept on the top of the bin. The moths that emerge out from the grain burrow through the sand and come out but cannot get inside to lay eggs in the grain and thus, further multiplication is controlled. Small samples of grain stored in bottles in laboratories can be kept free by putting a napthalene ball inside each bottle.

Diseases of rice

Blast disease.—Compared to other crops, the number of diseases which rice is subject to, must be considered relatively few. By far the most important disease of rice in South India is the ' blast ' disease caused by the fungus *Piricularia oryzae* (*Kollai novu* in Tamil and *aggi tegulu* in Telugu). This disease is known in almost all the rice-growing countries of the world. In its typical form it is the disease of the joints of the stalk. When the attack is in young plants, characteristic brown spots with ashy grey centres appear on the leaves. In course of time, the spots become larger. join together and finally the whole leaf turns brown and shrivels up. In older plants, the leaf spots do not spread so rapidly but the attack is more severe at the nodes, and in severe cases the fungus attacks the ' neck ', i.e., the spot where the stalk passes into the axis of the earhead. In such cases the grains are poorly developed and the earhead breaks off at the diseased spot. In a badly infested field the entire crop has a blasted appearance and the loss caused is indeed very great.

The fungus is propagated through its spores and mycelial threads. In a dry condition, the spores have been found to remain viable up to six or seven months, a period sufficiently long to bridge the gulf between two successive rice crops. Experience at Coimbatore goes to show that the disease occurs year after year in a previously infested field provided a variety susceptible is raised in it. The fungus is spread from plant to plant through the agency of wind and rain. Infected straw and chaff are responsible for the dispersal of the fungus to much greater distances while infected grain distributed through human agency, carries it across all natural barriers.

Under South Indian conditions the outbreak of the disease is closely linked with the weather prevailing during the rice season. The sporadic nature of the outbreak and the rapidity of spread do

not admit of any preventive or curative measures. Spraying with bordeaux mixture may control the disease in the nursery but is impracticable in the transplanted crop.

Intensive studies have been carried on to determine the relative resistance of several varieties of rice to this disease. These showed, that within certain limits, the early maturing varieties had a relatively lower percentage of infection, but there was a wide range of variation even among varieties of approximately equal duration. Various morphological differences among varieties like the size and inclination of boot-leaf, the degree of emergence of the ear, the type of the panicle—open or bunched, etc., appeared to have a relation to the intensity of infection. Another thing that was noticeable was that portions of crop situated in an extremely fertile patch characterised by excessive vegetative growth showed relatively more infection than in other portions. Application of nitrogenous manures is also found to induce susceptibility to the disease.

The only methods of combating the disease appeared to be to avoid growing really susceptible varieties and to breed specially resistant varieties. The knowledge that varieties like GEB. 24, Co. 1 and Co. 4 are highly resistant to the disease has been made use of in making suitable crosses between these resistant and other susceptible varieties and the results have shown great promise as already explained.

Rice foot-rot (*Thoor azhukal noi* in Tamil and *Adugu kullu* in Telugu).—Another serious disease of rice is the foot-rot, caused by a fungus, *Fusarium Sp.* This has been found in Godavari and Coimbatore. The disease resembles in its effects the ' bakanae ' disease of Japan and ' man disease ' of British Guiana.

When the disease attacks the seedlings, the damage is very serious. The disease causes paling of the leaves, elongation of the stalk and in course of time the entire seedling dies. Seedlings may start dying from as early as the sixth day after sowing. In the transplanted crop the damage is not as bad as in the nurseries. The most characteristic symptom in the transplanted crop, is the appearance here and there of tall lanky tillers, shooting up conspicuously above the general level of the crop. The abnormal elongation of infected tillers appears to be due to an accelerated growth at the expense of lateral development. Plants which show this sympton invariably show fungus attack at the collar region and die within a period of two to six days. Another symptom associated with the disease is the development of adventitious roots from the nodes above ground level. No earheads are formed as a rule. A few that may be formed are chaffy.

Observations have been made with regard to varietal variation in resisting the attack of the fungus. They showed that none of the varieties examined were absolutely immune to the disease but

varietal differences ranged from the verge of complete resistance to almost total susceptibility.

Since the studies on the fungus have given evidence that the disease is primarily seed-borne and that seedlings take infection at the period of germination, various seed treatments have been tried to control the disease. Though most of the treatments adopted showed less disease than the controls, formalin, hot water, copper sulphate, ceresan, upsulun, senesan and granosan (all patent preparations) produced convincing results. Of these, ceresan and granosan are used in the dry form and hence the advantage that even if the treatment is done before the period of sowing, they do not affect the germination of the seed. Moreover when treated in advance the possibilities of re-infection through infected granaries, etc., are eliminated. There are special mixing machines which can be used to treat the seed thoroughly.

Helminthosporium oryzae (*Pulli noi*, Tamil, *matsa tegulu* Telugu).—This is known to occur in all rice areas. It is said to be a serious disease in Japan and often spraying the crop with Bordeaux mixture is resorted to.

The disease is characterized by small brown linear spots on leaves and may under favourable circumstances cause the blackening of the necks, nodes and grains. The earheads are sometimes affected and they do not emerge from the leaf sheath. Individual grains may also be affected. This disease first appeared in Godavari and Kistna in 1918–19 and a heavy damage was reported.

The fungus spreads through spores borne on the leaves, stalks and grains. The fungus can live in the seed and be carried from season to season. Seedlings raised from infected seed are often subject to a 'seedling blight,' the dead seedlings forming the medium for the saprophytic development of the fungus, and the spores blown about, serve as a secondary source of infection.

The fungus is not a virulent parasite and attacks only plants weakened by other causes. There are no special methods of control except destruction of infected stubbles and using seed from a non-infected crop.

Sclerotial disease (*Sclerotium oryzae*).—This is a minor disease of rice caused by a fungus. It occurs only here and there and is not known to cause any appreciable damage to the crop. The disease escapes the attention of the cultivator in the early stages when the infected plants can be differentiated from the healthy ones by the peculiar form of 'tillering' at the base of the infected culms. Infected culms turn yellow and die. Grains are poorly developed and the glumes are in most cases empty. In many of the localities where the disease has been noticed the disease appears late in the season when the crop approaches maturity. The disease develops mostly in water-logged localities and is not to be seen in well-drained fields.

The sclerotia of the fungus are capable of living in the soil for several years but the question of application of chemicals aimed at killing the fungus is out of consideration for a crop like rice. While the permanent method of controlling the disease may be by breeding resistant varieties, the following precautionary methods may be adopted. The infected plants as soon as they are noticed may be removed and burnt. The planting may be done thin to prevent over-crowding. The infected straw should not be carried to uninfected areas.

False smut of rice (*Ustilaginoid virens*) (*Nel pazham*, Tamil, *Vari pandu*, Telugu).—This is known to occur throughout the rice areas, and is characteristic of a bumper crop. The life history of the fungus is still not known. Even very severe cases of attack when estimated did not amount to more than 1 or 2 per cent. of the total earheads and even then only a few of the grains are affected, the rest remaining normal and healthy.

In the affected earheads, some of the grains are not formed but swollen masses of fungus tissue, yellowish first, turning dark-brown later, fill in the cavities between the glumes. The young ovary is invaded by the fungus at an early stage in its development and is transformed into a hard mass.

CHAPTER XXV

COST OF PRODUCTION

The agricultural practices and the acre yields obtained vary so much from tract to tract in the Presidency that it will not be possible to compare the profits realised from rice cultivation. There is not much variation in the methods of cultivation, and the chief differences in the cost must, therefore, depend upon the standard of cultivation and the cost of labour in the different tracts. One of the chief items in the cost of cultivation will be that due to manures and manuring. This again may vary from practically nothing to as much as Rs. 15 to Rs. 20 an acre. In tracts where bigger acre yields are obtained, some money is usually spent on manuring or it may be that because some money is spent on manuring greater yields are obtained. The question of expense on manuring also depends upon the size of holding and the nature of tenancy.

It is not possible to obtain reliable figures from private cultivators about the costs of cultivation. In large holdings the owner does not usually maintain accounts, and in very small holdings the cultivator himself and the members of his family contribute to most of the labour necessary for the cultivation. Small cultivators grow rice not because it pays them but because they get some produce to live upon. They do not value their personal labour devoted to its cultivation.

To get some idea of the cost of production relative to the prevailing price of the produce in the different tracts, the following data are given. They have all been taken from the figures available at the different agricultural research stations of the Province. Though the figures relate only to the non-experimental areas of these stations, they must be considered higher than what obtain in the neighbourhood of the station. Generally better attention is paid to cultivation and manuring at the Government stations and the yields are also proportionately higher. The figures given below represent the cost of producing one hundredweight (112 lb.) of grain in husk in the different tracts before 1930 when the present depression had not set in.

Station.	Year.	Yield per acre in lb.	Cost of cultivation per acre.			Cost of producing 1 cwt of paddy.		
			RS.	A.	P.	RS.	A.	P.
Palur	1927–28	3,094	65	13	5	2	6	4
	1932–33	3,094	46	5	9	1	11	0
Samalkota	1928–29	3,000	69	6	2	2	8	2
	1932–33	3,000	49	0	1	1	13	4
Kalahasti (semi-dry)	1928–29	2,000	50	3	7	2	12	8
	1932–33	2,000	31	4	1	1	12	0
Taliparamba	1928–29	2,000	55	15	7	3	2	2
	1932–33	1,800	42	1	6	2	9	11
Coimbatore	1927–28	4,100	79	10	10	2	3	0
	1933–34	3,472	74	8	0	2	6	6

The cost of cultivation which includes, preparatory cultivation including planting, manuring, seeds and sowing, after cultivation, irrigation, harvesting, threshing, etc., is found to vary from Rs. 56 at Taliparamba to Rs. 80 at Coimbatore and the cost of producing 1 cwt. of rice in husk varied from Rs. 2–3–0 at Coimbatore to Rs. 3–2–0 at Taliparamba. It shows that the greater the cost of cultivation, the larger the acre yield and less is the cost of production. The prevailing market rate for the grain varied between Rs. 5 and Rs. 5–8–0, so that the cost of production comes to nearly half the value of the produce. The lower the cost of production relative to the value of the produce, the larger must be the margin left for the cultivator to meet his expenses, as rent on land (if he is a tenant), assessment, interest on investment, etc.

After 1932–33 the cost of labour has gone down and hence the cost of production also has come down relatively and it varies only from Rs. 1–10–0 to Rs. 2–10–0 per cwt. of grain. The figures from the different rice stations, Coimbatore, Maruteru, Aduturai, Pattambi and Berhampur for 1933–34 vary from Rs. 1–6–0 to Rs. 2–14–0 for the single crop and between Rs. 1–9–0 and Rs. 2–4–0 for the double crop lands.

The Deputy Director of Agriculture, VIII Circle, has collected figures for the cost of production in rice from six ryots in the Salem district prior to 1930 and they are given below along with some figures collected for three other centres in South Kanara, Vizagapatam and Bellary, by the respective demonstrators :—

Station.	Year.	Yield per acre in lb.	Cost of cultivation per acre. RS. A P.	Cost of producing 1 cwt. of paddy. RS. A. P.
Salem	1930	3,420	110 6 0	3 9 6
Do.	1930	2,588	105 14 0	4 10 9
Do.	1930	3,150	123 8 0	4 6 0
Do.	1930	1,688	67 6 0	4 7 0
Do.	1930	2,250	79 7 0	4 10 0
Do.	1930	2,828	76 3 0	3 14 9
South Kanara	1930	1,885	40 6 0	2 6 0
Vizagapatam	1931	1,968	27 15 0	1 9 6
Bellary	1932	3,600	38 15 0	1 3 6

In Salem for which figures are given, rice is grown as a well irrigated crop and the cost of cultivation is nearly double that given in the first table. Nearly a third of this figure relates to the cost of lifting water. The cost of producing one hundredweight of rice in husk by well irrigation is more than double that by flow irrigation and even then there was left a safe margin for the cultivator to meet his other expenses from, as the price of grain was high. With the present price of rice, the cost of production by well irrigation should almost amount to the cost of produce, leaving no margin for the cultivator. The figures given for the other three centres compare favourably with those given for the Government stations.

CHAPTER XXVI

PURE PADDY SEED AND HOW THE RYOT MAY KEEP IT PURE

For many years the Department of Agriculture, Madras, has been distributing pure paddy seed, but the demand has almost always exceeded the supply. If cultivators were alive to the necessity for maintaining pure seed stocks, it would not be necessary for them to come back to the Department of Agriculture every year, or two years, for fresh seed. The Department of Agriculture will never be able to supply fresh seed to all those who apply, and if more people who have once had a supply would look after their own seed stocks carefully, the department would then be able to distribute its stocks to new applicants each year, and so the improved seed would spread more quickly.

Pure seed means pure crops; pure crops mean uniform germination of a high order, leading to uniform growth (all the plants of a field coming up together, flowering together, ripening together). Attacks of disease or pest so common when patches of plants ripen one after the other are reduced to a minimum. Irrigation is made as simple as possible and there is a minimum of loss at harvest because all the grains are at the same stage of ripeness. The resulting uniformity of grain commands a better price in the market. The ryot who follows the suggestions given below can sell his produce for seed, thereby commanding at every stage pure seed at an advantage, and the extra trouble that is necessary in maintaining the purity is amply repaid.

How impurity arises—Seed-beds.—These may be prepared either wet or dry. Although dry seed-beds offer certain advantages in some districts, and may even be essential, they offer a fruitful source of mixture of seed. Cattle are commonly tethered on ground intended for the dry nursery, and rice straw is used as fodder. As this straw has, in the majority of cases, been cattle-threshed, it usually contains odd grains, and these may easily establish themselves in the ground and come up with the subsequent nursery seedlings. If the paddy straw intended for feeding is stacked on the fields, there is the possibility of the vitality of any stray seeds being destroyed by the natural heating in the stack. The practice of stacking paddy straw and sunn hemp hay in alternate layers, common in the Godavari district, is good in that the stack heats up to just the right extent and minimises the danger of stray grains sprouting.

Sweepings from the threshing floors are often added to the nurseries. Though the idea underlying this may be to increase the organic content of the soil and so to improve its texture

and fertility, it is a bad practice. These sweepings are full of stray grains and probably contain weed seeds, seeds of other plants, diseased chaff, etc. They are much better burnt, and the ash then becomes a useful manurial dressing.

In the dry seed-beds of Malabar, seeds of the first crop shed in one year are liable to remain and sprout in spite of all precautions. This is a difficult question as it is often impossible to obtain water in time for first-crop nurseries and dry nurseries become a necessity. Stray seeds of the second crop do not appear to cause trouble, and if the nursery for the first crop is laid down in a field that was growing the same variety in the previous year, there is no particular danger in the "voluntary" seedlings, as they are identical with the mass. The remedy here lies in using one nursery for the same variety, year after year. If this is done, much of the disadvantage of the dry nursery disappears.

In deltaic tracts under canals or channels where advantage must be taken of the first flood, wet nurseries are commonly sown all over the tract at the same time. Usually corners of fields, or fields in compact blocks, are taken, and field-to-field irrigation is the rule. As every one is clamouring for water at the same time, no precautions are taken against washing seed from one field to another. If all the nurseries are of the same variety, the damage due to such washing away of seed may be slight; but as all varieties may be sown together, in contiguous nurseries, mixtures are bound to occur. The remedy is easy if the disposition is planned beforehand. The position of the fields that can be used as nurseries is fixed in relation to the source of water, but what is usually at fault is a lack of system in separating varieties. Where nurseries are raised on a large scale and the seedlings are sold to other ryots at varying distances, the danger is minimised; when the nuresries are necessarily small, a little co-operation amongst the cultivators along the same channel could prevent any danger of mixture.

In broadcasting seed for the nursery, or where transplanting is not practised for the main fields, the ryot usually likes to get into every nook and corner of the field and to sow each small field channel, and in his zealousness a little seed is blown over the bund or is washed along the drain into the next field. This is another common source of mixture and the remedy is to discard border seedlings in a band at least one yard wide all round the field. These border seedlings may be used for transplanting into fields that are not intended for seed, but for seed purposes only those seedlings from the centre of the nursery, which are beyond suspicion, should be used.

In cases where several small plots of different varieties are sown in the same nursery, the little patches of different seeds are demarcated by clods of earth or twigs lightly stuck into the

ground. These are easily moved or washed away and the confusion which results is a certain cause of mixture. The same condition arises when surplus seedlings of different strains or varieties are transplanted in plots along with the main bulk. The plots are again demarcated by mud lumps. The remedy is to use some more permanent boundary such as a field drain or a bund, and the importance of leaving a reasonable space between nurseries of different sorts of seedlings cannot too strongly be stressed. It is not a waste of space. It is an insurance. A space of two feet is quite sufficient in a nursery, with reasonable care, to minimise the danger of mixing.

In many cases (particularly on the West Coast) deliberate mixing of seed of similar varieties goes on, as this practice is said to minimize seasonal effects and ensure at least an 8-anna crop in bad seasons. It may. But a maximum crop is never attained. Examples of this custom are *vettuvari* and *vattan* in *palliyal* lands (single crop), and *veluthanikazhama* and *aryan* in double-crop lands. Such crops should not be used for seed. Nor is it certain that the custom has much to recommend it.

When seedlings have been pulled out for transplanting, the nursery is hurriedly cultivated and some seedlings are replaced. Stray seedlings may, however, persist, and when several varieties are grown in the nursery these may be a source of contamination. Cases where this occurs are not frequent, but in no case is it wise to use a nursery for the source of seed stocks, and the subsequent cultivation will have removed the danger in time for the next crop. As far as possible the position of the nursery should remain unchanged year after year when rice follows rice with no rotational crops. Not only will the fertility of the nursery block be maintained and built up thereby, but the risk of contamination by stray seedlings is lessened by the extra attention that is given to the nurseries.

The danger of " voluntary " seedlings mentioned above in dry nurseries is not so great in the case of wet nurseries. If water is available the best method of cleaning up fields suspected of harbouring stray grain is to plough and let in water to soak the field for three or four days. As the water dries out the grain will sprout. Some grain will take longer and an interval of at least a week should be allowed so that all seeds have a chance to germinate, and then the plough should again be used. The seedlings will soon decay and the danger is removed.

Transplantation.—Fields to be used for planting should, where possible, be freed from shed grains by germinating the grain and ploughing in the seedlings just as for seed-beds. This may not be practicable over the whole area, but it is particularly important for the portions set aside for seed purposes.

One nursery may be sufficient to plant up the holding, and seedlings from another nursery—and quite possibly a different variety—are frequently used to fill up fields without leaving any space or boundary. This is unfortunately, only too common in the initial stages of trying the strains from the Paddy Breeding Stations. So heavy is the demand for the seed that applicants usually have to be content with only a portion of their demand. This means that they must fill up their fields with other seedlings, but in the process the dividing line is not kept and the whole field is harvested together. The result is almost certain to be a mixture of types. The remedy is simple and consists merely in separating the different types by drains or bunds, and harvesting and threshing them separately.

Another result of this mingling of types in the same field is the possibility of natural crossing occurring among the plants where the two types meet. The seed of that generation will escape detection, but the plants of the next season will show a "degeneration." The remedy lies in discarding (for seed purposes) a border of at least three feet in each type, i.e., a band of six feet where two varieties touch. This grain is saleable for food but the seed grain must be harvested and threshed separately.

How natural crossing results in deterioration may be explained. It must be common knowledge to all who deal with rice that there are enormous variations in the characters some of which follow the mendelian inheritance. As a rule, each paddy flower is closely self-pollinated, and by the time the six anthers and the two feathery stigmas are visible, pollination has been effected. The anthers may not, however, shed their pollen until five minutes after they appear, and in very unfavourable conditions, such as dull weathêr, the anthers and stigmas may be outside the glumes much longer without pollination occurring. It is therefore obvious that there are distinct chances that pollen from one plant may find its way on to the stigmas of another, and so effect a cross.

In fields growing different varieties side by side there are possibilities of such crossing occurring on the edges where the two varieties meet. Suppose a variety, red *sirumani* of Tanjore, was growing next to *nellore samba* and pollen from the latter fertilized a stigma of the former. There will be no external evidence. The grain will set normally. If it is sown in the next season the resulting plant will have red *sirumani* type of round grain and will be indistinguishable in this respect from others. In the second year the case is quite different. The first generation F_1 plant may have produced 500 to 1,000 or more grains. If 500 of these grains are sown and they produce plants, there will be approximately 375 with round grains and 125 with long *nellore samba grains*. In future years there will be a constant splitting of the hybrid round type in the ratio of three round to one long. It is therefore obvious that contamination due to such crossing may escape attention in

the first year, but, once established, it is extremely difficult to arrest. As it may occur every year round the borders of fields, the remedy should be obvious—grain for seed purposes should always be taken from the centre of the field away from all danger of contamination, and it must be threshed separately and treated carefully at each stage to ensure purity.

The advantages of transplanting over broadcasting are many, but one that is not often thought of is that there is much greater control over the mixing of strains. If seed is broadcast in a field which already contains stray seed, both the broadcast and the stray seeds will grow up together and there will be no chance of separating the mixture. If, however, this foul field is used to receive transplanted seedlings, there will, from the start, be a difference between the seedlings already equipped with leaves and stray seeds that may eventually sprout, and therefore it is easy to destroy the stray seedlings. The extra space between seedlings of a transplanted crop makes this separation still easier.

If a patch of transplanted or broadcast crop dies out from any cause, e.g., a water pocket resulting from faulty levelling, crab damage, etc., and the nursery is empty, it is better to pull out seedlings from the same field to fill up the gaps than to take seedlings from someone else's nursery about which little is known. Exchange of seedlings is very common in some of the larger deltaic tracts and is the cause of much mixing.

Growing period.—The ryot naturally wants to use every square inch of his field and looks with disdain upon the " stupid " practice of walking into the fields and pulling out stray plants. It is all a question of view point. If the crop is for feeding only, a slight mixture of grain has little bearing on the market value. Therefore there is no particular financial advantage in roguing food crops. But for seed purposes roguing is a first essential and neglect of this operation stultifies all efforts at maintaining purity.

It is equally important that roguing should be done by uprooting the whole plant and removing it from the field. Cutting off the vegetative portions with a sickle is of no use as the plants will send up secondary tillers (ratoons) which hurry through their growth and may mature with the main crop. The grain is thus included in the harvests and the work of roguing wasted.

Roguing must be carried right through the growing period. It is not a difficult process and an intelligent coolie can be trained to do the work. There is no particular period at which roguing should be done as the difference in growth of stray plants may be more obvious at one stage than at another. Thus a first generation hybrid may rush through its early stages and become obvious by its extra height and vigour in the first month. An early, short

term variety will be obvious immediately it shows signs of flowering and may easily be spotted amongst the bulk of flowering. As a general rule the pre-flowering and flowering stages offer the greatest chances of noticing differences.

Generally speaking roguing need only be done on plots intended for seed. It is always better to do too much than too little and about one-fiftieth of the holding should certainly be treated and this must be done every growing season.

Threshing.—The threshing floor is perhaps the most obvious source of contamination. There is no need to advocate expensive floors of stone or cement as the ordinary mud floor can be made quite serviceable in the way common to the country-plastering with cowdung. The chief disadvantage of an earthen floor is that it develops cracks. These should be attended to at once, as they are a source of loss as well as of contamination.

In some tracts high land for threshing floors is very rare. An ordinary field is then used and this should on no account be put down later to a nursery or should seed bulks be raised on it. The dangers of using it as a nursery are that seedlings sprouting from stray grains are liable, on transplanting, to find their way to any part of the holding and so get hopelessly mixed in. Such a threshing floor should, therefore, be chosen only in a field used for raising food crops.

In some districts, because of the shortage of high pieces, threshing floors are used by several ryots clubbing together and these form a serious source of contamination. Different varieties are all threshed out on the same ground and mixtures, which must inevitably result, thus find their way into the grain of every ryot, and the owner of the field suffers most. It is impossible to stop this system, which is dictated by necessity, and the only remedies are to thresh out seed stocks separately, and to insist on perfect cleanliness (by sweeping after every lot is done, closing up cracks immediately with mud, and by giving the whole floor a further coating of cowdung).

Grain intended for seed is often taken out of the bulk after all is threshed. This is a hopeless state of affairs. There are hundreds of agriculturally different types of rice, but it is not possible to distinguish them all by their grains. Therefore it is not possible to separate them in the mass once they are mixed. The only way of ensuring purity is to stop them getting mixed in the first place. Thus there is only one satisfactory way of saving seed and that is to grow a special plot for that particular purpose. If only one quarter of the ryots cultivating rice could be prevailed upon to grow special seed plots, the difficulty of supplying enough seed to go round would soon disappear. Seed plots should be threshed first and, where possible, they should be hand-threshed or trodden under foot by coolies.

Winnowing should all be done in one place as far as possible to avoid the distribution of grains that may be light but would still germinate. In a high wind these may be blown about the floor, into the fields, into the heap of threshed grain, etc. Hence the importance of protection from high winds.

In Malabar practically every cultivator has his own threshing floor and here the difficulty is not one of the common ownership but rather that one man may deal with a number of varieties. All these varieties are threshed on the one floor, advantage being taken of snatches of sunshine, and with very little cleaning in between. The remedy here is obviously a closer attention to cleanliness.

Seed drying.—Frequently along the border of a roadside-village one sees grain spread out on a mat to dry. This may be food-grain being dried for pounding but is often seed-grain. Undoubtedly the drying is necessary but the care taken of it bears no relation to its value. A properly cowdunged floor with a certain amount of privacy offers better facilities than a mat in a public highway. The mat is likely to catch grains in its meshes and these grains may become a part of the next pile to be dried. The mat is considerably improved if it is washed over with a thick suspension of cowdung before use, as this closes up most of the cracks and holes; but whatever other precautions are taken, the grain should be kept away from public places where there are so many chances of contamination and loss.

Seed storing.—There are many receptacles called into use for storing seed. One may mention gunny bags, mud pots, mud bins, bamboo bins, wooden bins, *mudikattas* or straw twists, *pattarais* of straw twists, pits, granaries, etc. Each method has its merits and demerits. Thus gunnies are convenient for filling and they hold a recognised quantity for sale, and are cheap. If care is taken to see that no stray grain has been left behind in the bag before it is used, the gunny makes probably the most convenient means of transport and temporary storage. It is not insect or rat proof, nor is it damp proof, and insects and damp are the worst enemies of stored grain. The gunny cannot be said to be a good receptacle for storage, and it has many disadvantages. But it is convenient, and is in such common use that it is unlikely that it will even be replaced. Again, the maxim is cleanliness. If the grain is occasionally spread out on a floor open to the bright sun, much can be done to keep the grain in a good condition. Sun light is the best cure for storage ills. Mud pots and mud bins may be made insect proof by a covering of cowdung. Storage receptacles (pattarais, etc.), made of straw twists are built up as required and dismantled after use, but their danger lies in the introduction of stray grains by half-threshed straw of another variety. The large granaries of the Godavari, like little houses, are usually kept very clean and each year before new produce arrives they receive a fresh coating of cowdung inside and new thatching outside.

Germination test.—Before any seed is sown it is an excellent practice to conduct a germination test. If, for instance, it is known that a sample will only germinate 50 grains in each 100, it is clearly necessary to double or even treble the sowing rate to get an even stand. As a matter of fact seed so bad as this should at once be discarded unless it can be improved by further exposure to the sun. But an 80 per cent. germination also needs more seed for sowing than a 99 per cent. germination. Bad samples are easily found out in this test. A sample of which the seeds germinate all together on the same day is good, but some samples will spread out over a number of days. The disadvantage of this in the field is obvious and may often be avoided by further drying.

A simple germination test may be carried out on 100 grains taken at random and put between cloth or blotting paper which is kept moist. Examination at the same hour each day for three or four days will soon show the rate and amount of germination. Moist sand or earth may also be used, but it is better to do such tests in the dark in such a way that there are no sudden changes of temperature. A square unglazed tile (porous) divided into 100 squares and placed in shallow water so that it is always moist forms a very convenient germination plate, but it should be covered, as light has a definite retarding effect on germination.

Conclusion.—The purity of a crop can only be kept up by incessant care. The above notes touch on several points where contamination may easily occur, but a little thought will extend this list greatly. Fortunately it is not necessary to apply these precautions to the whole of the crop. Few cultivators will require more than one-fiftieth to one-hundredth of their holding for raising seed for their own use, and attention should be concentrated on this. In any field from which rice for seed purposes is taken whether it is a special seed plot or an ordinary field, the borders should always be harvested separately and used for food; only the central portion of the field, about which there is no fear of contamination, should ever be taken for seed. At other stages, such as threshing, particular care is again needed for the seed grain, though nothing has been advocated above that might not easily be applied to the whole crop with advantage.

If it could be said that, in each taluk, there were three cultivators in a fairly large way who could be relied upon to raise pure seed stocks each year, there would be no more difficulty in meeting all the many demands for good seed. The Department of Agriculture will never be in a position to sell seed to all who wish to grow strains, and the most satisfactory way of making the supply meet the demand is to increase the local supply.

CHAPTER XXVII

RICE OUTSIDE MADRAS AND OUTSIDE INDIA

Rice is an important crop of some of the other Provinces in India as well as of some countries outside India. While it is not possible to describe elaborately the methods of cultivation in such provinces and countries, in the following pages are mentioned some of the salient and special features, culled from publications.

Besides Madras, Bengal, Bihar and Orissa, Burma and Assam are the other chief rice-producing provinces. But most of these except Burma only produce rice just enough or little less than their own requirements.

Bengal, Bihar, Assam and Orissa.—The main rice area of Bengal comprises the delta of the two great rivers, the Ganges and the Brahmaputra. The delta is interlaced with a number of water-courses and the main problem of the delta is to get the water off from the fields. A considerable area is subject to heavy floods. Bengal is also rich in varieties.

In Bengal there are three distinct groups of rice, *aus*, *aman*, and *boro*, terms used to denote the rices grown in particular seasons. The *aus* varieties are always sown broadcast in summer and reaped in August-September. There are again two groups of *aus*—one that is grown on highlands in April-May and the other grown on low-lands in February-March. The latter usually grows in 5 to 6 feet of water and the harvest is generally done in 3 to 4 feet of standing water. Of the *aman* varieties there are again two kinds; one of which the transplant *aman*, the most important of all the groups, is sown in seed-beds in June, transplanted in July-August and harvested in November-January. The other *aman* is usually broadcast in very low-lying areas during March-May and harvested in December-January when the flood waters have dried up. Some of these low-land *amans* can grow in even 20 to 30 feet of water. The last kind, *boro* is comparatively of less importance than the other two. The seed is sown in seed-beds in October, transplanted in December in places where water does not dry up even during the cold weather and is harvested in March.

There is practically no rotation followed in rice lands except the growing of jute alternating with rice in parts of Eastern Bengal. Occasionally when conditions are favourable a small pulse crop may be sown soon after the rice harvest. The rice fields do not also receive any manure generally, even the small amount of cattle-dung available being burnt away as fuel.

The conditions of rice growing in Bihar, Orissa and Assam are not probably very different from those of Bengal. Rice is both directly sown and transplanted, the varieties used being different for the two treatments. There is also a good area under deep-water rices in Assam and Orissa. While in Madras ploughing the deltaic lands in summer has been found to be harmful, in parts of Bihar, the practice has been found to be actually beneficial. Usually a *pyru* crop is sown in the standing rice just before harvest which grows and matures in the cold weather. Such pyru crops are usually leguminous, the most common being peas, lentil, gram, etc. Though in parts of Bihar transplanting is found more advantageous than broadcasting, the advantage has not been so apparent in Orissa. In the latter place it is the usual practice to plough the broadcast fields at a later stage which serves the purpose of both weeding and thinning the crop.

In the United Provinces the main rice season is from June to October and both broadcasting and transplanting are practised. While this crop is grown mainly with the help of rains, occasionally a second crop may be grown if irrigation facilities exist. In parts of the Central Provinces and Berar rice is generally broadcast and is rarely irrigated. In black-cotton soils it is generally grown as a catch crop before wheat. Even in places where irrigation tanks exist transplanting is never practised. Application of small quantities of ammophos to the seed-beds has been found to give profitable results.

In Bombay and Sind rice is principally a ' *kharif* ' crop depending upon rainfall. No rotation is followed generally, but sometimes, under favourable conditions, castor, gram, etc., are grown. In parts of Guzarat, the practice of green manuring for rice is common. In Kanara and the forest areas of Dharwar green leaves are usually brought from the adjacent forests and applied to rice fields. In several parts of Bombay, the application of sulphate of ammonia to supply 30 to 40 lb. of nitrogen in two stages, one at planting time and the other a month later, has been found to be profitable.

Burma.—The development of rice cultivation in Burma, the chief exporting Province of India, is of recent date. Before the third decade of the 19th century, the crop was grown mainly for home consumption and there was practically no export trade. Since the advent of the British, areas which remained as swamps previously are now grown with rice. To quote Grant, Rice Research Officer, Burma, "A feature of the history of paddy cultivated in Lower Burma in contrast with that of the older rice-producing countries of the east is that almost the whole of the area has been brought under cultivation during the last sixty years by small cultivators producing for an export market, the work having been financed mainly by Madras Chettyars. In Upper Burma, the extension is due mainly to irrigation works carried out by Government."

The bulk of the rice is produced in the low-lying delta lands and the coastal plains. Over 80 per cent. of the crop is produced in the stiff alluvial clay soils of Lower Burma where the crop is entirely rainfed and it is from here that the whole of the exportable surplus comes. In Upper Burma, however, the rice crop is mainly grown with the help of irrigation. The general practice in Burma is to transplant rice but in some tracts where labour is scarce or where the crop cannot be got in in time the seed is sown broadcast by hand.

By far the most important of the varieties grown take about six to seven months to mature while shorter duration varieties are grown on a small scale wherever water facilities are not so assured. In Lower Burma rice is grown year after year on the same land and so far no other crop which might be grown in rotation with it has been discovered. Even in Upper Burma where some rotation is possible rice is cultivated in preference to any other crop. Little or no manure or fertilizers are applied to the rice crop in Burma. Cattle-dung is sometimes applied to the nurseries. Elaborate experiments have been carried out by the Burma Agricultural Department with all available manures and fertilisers. While well-preserved cattle-dung applied at the rate of 3 to 4 tons to the acre may give a 50 per cent. increase in yield, there is not much of it available and what little is available is of a poor quality because of the little attention paid to its conservation. It has not been found possible to raise a green manure crop. Experiments with chemical fertilisers have given satisfactory results, the profits amounting to nearly Rs. 25 an acre when the price of rice was high. With the drop in price the profits are not more than Rs. 3 to Rs. 4 per acre now. The application of one hundredweight of ammophos to an acre of seed-bed has been found to give an increase of 10 to 15 per cent. in the final yields.

One chief feature of the Burma rice cultivation is the rather lower cultivation charges as compared to several other provinces of India. It is only about Rs. 15 an acre besides Rs. 3 paid as land revenue. Because of the chief export trade, greater attention has been paid by the Agricultural Department in Burma in evolving types suitable for milling purposes.

Bengal, Burma and Madras are the three Provinces where the crop has been studied by a botanist for over twenty years. Most of the available information about the rice plant in India has come from these three Provinces. A large number of improved strains has been evolved and distributed and a good portion of the rice area is grown now with these strains in these Provinces. Since the coming into existence of the Imperial Council of Agricultural Research six years ago, a large number of rice schemes is being financed by the Council in the various Provinces of India and in the different universities. The work has now been very much

intensified and considerable knowledge of a fundamental nature about this important food crop of this country is likely to be soon available.

Rice outside India

Japan.—Among the other rice countries of the east, Japan is by far the most important and the cultivation here is extremely intensive, much more than in any other eastern country. The coastal low lands and the river valleys are the most important rice lands. Hill rice occupies less than 2 per cent. of the area, ordinary swamp rice 90 per cent. and the glutinous rice the remaining 8 per cent. Over 85 per cent. of the rice crop in Japan is irrigated from rivers and reservoirs and the use of paddle wheels is a common feature to lift water to the fields from the rivers. The smallness of the rice fields and the steepness of the terraced hill sides to grow rice are noteworthy. One third of the total rice area takes a second crop also. What scientific agriculture can do to improve the crop is well exemplified by the work in Japan. The yields now obtained per acre is almost two to two-and-a-half times that prevailing 50 years ago, the improvement having been brought about by the practice of intensive methods, growing improved types, and liberal application of manures and fertilisers. Though Japan was not producing enough rice for her requirements in earlier years, her intensive cultivation and the extension of rice area in her colonies, Korea and Formosa, have made it almost self-sufficient in a normal year.

The rice crop is always raised in wet seed-beds, dry seed-beds being never practised and seedlings planted when 35 to 45 days old. The planting is always done in regular lines with the help of ropes made of paddy straw about 8 to 9 inches apart. One chief characteristic of Japan rices is that they are all short, being never more than three feet in height, and possess stiff straws and do not lodge even with heavy manuring.

The practices of composting all waste material with a view to apply it to rice fields, growing of a green manure crop and the liberal use of the human excreta have long been adopted by Japanese cultivators. The use of chemical fertilisers like super, sulphate of ammonia, in large quantities along with the organic matter (the proportion of the two being half and half) is an important feature of Japanese rice cultivation. An acre of rice crop easily gets about 70 to 80 lb. of nitrogen in the shape of sulphate of ammonia and about 50 to 60 lb. of phosphoric acid in the shape of phosphates. A large percentage of the sale of the chemical fertilisers is managed by the co-operative societies. Breeding of superior types has long been practised and it is stated that over 70 per cent. of the rice area in the country is covered by seeds of known parentage, there being a good control over the distribution of the seed. The number of varieties grown on a large scale is also very limited. The rice crop is generally planted in June and reaped in October. Rice is regularly rotated with other

cereals and leguminous crops. The application of phosphates in large quantities is usually done to the barley crop preceding rice. Weeding and harvesting are done by manual labour. Threshing and husking are done by small machines which can be worked by hand, foot or electricity. The rice straw is put to various uses, for making ropes, for making mats, for thatching and for making bags to bale the threshed produce.

The average yield of rice in Japan is over 3,000 lb. per acre and phenomenal yields of even 7,000 lb. of grain have been recorded in small selected areas competing for prizes.

China.—Rice has long remained the staple food of China. The crop is grown on the coastal low lands and terraced hill slopes of the country except in the north and in the western high lands where it is replaced by wheat, barley and other grains. There are no statistics available with regard to the acreage under rice but it is surmised it must be larger than in India. The estimated output of the country is also said to be much higher than in India.

Chinese rice culture from very ancient times has been done with manual labour and remains so still. As the great areas of intensive rice culture are flat, water has to be lifted to the fields, the labourers themselves being the commonest source of power. Unirrigated rice is also raised where the irrigation is impracticable and this is reported to be common in Manchuria.

The outstanding feature of Chinese rice culture is the use of manures. All waste of man and beast from city and country, is collected, stored without loss, allowed to ferment and decay and applied in liquid form to the land in small quantities so that nothing may be lost. It is applied intensively to the seed-beds and to the fields as a whole. What garbage there is, is similarly rotted and used with all other available organic matter. The sluggish streams and the canals are often dredged and the ooze is carried to the fields. Over most of the rice lands of China one crop per annum, occupies the ground from May until early September, but some districts in the south yield two crops in the year.

The average acre yields are said to be higher in China, than in any other eastern country except Japan.

Philippines.—Only a tenth of the total area is cultivated in the Philippines and of this about 50 per cent., a little over 3½ million acres, is occupied by rice. The rice production in the Philippines is not quite sufficient to meet the requirements and about a sixth of the annual production has to be imported. It is, however, stated that the use of selected seed and the adoption of proper methods of planting could make the production self-sufficient even without increasing the present area under rice. The best rice producing soils are heavy clays containing a sufficient amount of humus. Excepting a few provinces which have an irrigation system the majority of the rice areas depends upon the seasonal rains. Only

one crop of rice is generally planted and this is done in the beginning of the rainy season. Some of the irrigation systems have been built by private parties and commercial firms and a large number of farms is now irrigated by pumps.

The system of rice cultivation in the Philippines is very similar to what prevails in Madras. The different planting methods adopted are (1) the clearing of jungles, burning the material and sowing of rice corresponding to the *punam* cultivation of Malabar in Madras, (2) sowing dry seed either broadcast or by drill, practised in lands mainly dependent on rains and (3) the most extensive method of raising seed-beds and transplanting the seedlings. The advantages of transplanting over broadcasting have come to be realised and the former is gradually replacing the latter in certain areas. There is a special method of raising seed-beds, though not very common, adopted at times when the season is late and the regular method of raising nurseries might mean delay in planting. After the seed-beds are prepared by puddling the land, plantain leaves are laid over the surface of the mud and allowed to sink an inch deep letting the mud run over the leaves. The leaves are placed with the edge towards the centre of the bed, the split mid ribs thus forming a raised outer border. The ends of the long narrow beds so formed are closed with similar split leaves placed crosswise. The leaves are covered with a layer of rice chaff to a depth of an inch and a thick sowing of the sprouted seed is made on the surface. The seed-beds are carefully protected from the heat of the sun and during the early stages watering is done many times during the day. The roots of the seedlings get interwoven and the seedlings stand erect. By this method, transplanting, it appears, can be done much earlier, i.e., in 12 to 15 days after sowing.

The normal rice crop in the Philippines is said to require over 100 acre-inches of water. The varieties grown in the Philippines have all been classified and one prominent feature is that a larger number of bearded forms is still grown there, particularly for dry sowings. The average yield is stated to be about 1,700 lb. of grain per acre.

Rotation of crops is not generally practised as the rice lands in most cases are too heavy for other plants and the land once prepared for swamp rice is not adapted to the culture of other crops, particularly because of the large number of field bunds which should make the cultivation very expensive. Occasionally a pulse (gram), or maize is grown after rice.

There is no systematic practice of fertilising the rice fields followed in the Philippines. From observations made in the rice growing districts it is believed that thorough preparation of the land, systematic rotation of crops, the proper use of water and use of selected seed will have a greater effect upon the yield and will be more profitable than the application of fertilisers. Results of experiments have shown that sulphate of ammonia is the best form

of nitrogenous manure. The importance of organic matter for the rice soils is recognised here and the application of chemical fertilisers by themselves is not usually recommended.

Malaya.—The rice area in Malaya is scattered throughout the peninsula and it varies from year to year, the chief cause of such variation being the uneven distribution of rainfall. About 6½ lakhs of acres are under rice which form about 2 per cent. of the total area. Irrigation on a small scale is a common practice in Malaya. Water wheels and other mechanical contrivances for lifting water are also employed to irrigate small areas in some parts. The Government is endeavouring to encourage the extension of rice cultivation by placing more irrigable land at the disposal of cultivators. Malaya produces only a little more than a third of her rice requirements and the balance has to be imported. Burma has remained the chief supplier of rice to Malaya.

Since the soils vary very much from place to place in the peninsula, the methods of cultivation also vary. Broadly there are two types of cultivation, the wet rice and the dry rice. The wet rice cultivation does not differ much from what obtains in Madras and both dry and wet nurseries are used to raise seedlings. In some coastal districts rice lands consisting of very heavy clay become so soft and plastic when wetted that there is no necessity for ploughing. The preparation of a wet nursery for such lands is somewhat special and peculiar. The grass found growing thick in the fallow lands is cut and piled up into a long strip usually 3 to 4 feet wide until the pile stands about an inch above the water-level. On this grass foundation sufficient clay is plastered to make the whole into a compact bed on the top of which a thin layer of mud rich in humus is finally laid to complete the seed-bed. If the level of the water in the fields should rise; the nursery rendered buoyant by its grass foundation, floats and maintains its surface above water-level.

The dry cultivation consists of two kinds. One is the clearing of the jungle, burning the vegetation and then taking two or three crops of rice and then leaving it fallow for a period of years. In the other, the preparation of the land and sowing are done dry and, after three or four years cultivation, is left fallow for a similar period.

In planting, a simple implement is used (goats' hoof) with the help of which the seedlings are thrust into the mud without the planting coolie having to stoop down continuously. Greater spacing is usually allowed between plants in Malaya than in other places, varying from 10 to 18 inches according to the fertility of the soil. There is also the practice in Malaya of dipping the roots of the seedlings in a manure paste commonly consisting of a mixture of guano, cowdung or bone meal just before planting. Double transplanting is also practised to a small extent.

Though green manuring is not practised as such, the thick and rank growth of grasses and weeds which sping up between two rice crops is cut down and incorporated into the soil before the rice is planted. As the water-supply is not controlled in most rice areas and as the rainy seasons are not very well defined the growing of special green manure crops is not always a success. Experiments at the Government stations have, however, proved the possibilities of growing green manure crops in Malaya. The use of fertilisers is little practised in Malaya though their effect appears to be promising.

Except in very small areas worked by Chinese market gardeners, who grow vegetables, no crop is grown in rice fields after the rice. Experiments have, however, shown the possibilities of growing crops like sweet potato, groundnut, castor, maize, etc., as catch crops after the harvest of rice.

The yield in Malaya varies from 1,200 lb. to 1,700 lb. grain per acre. In the best land after paying for all labour, a net profit of Rs. 40 per acre can be realised. The profits would go down to about Rs. 10 in second-class ordinary land and in the case of poor land no profit is obtained if labour is to be employed, except in very good years.

Siam and Indo-China.—Rice is the chief product of Siam and nearly fifty per cent of the produce is exported from the country. The major portion of the rice that is available for export is grown in the plains and the deltas between the large rivers that empty themselves into the gulf of Siam. The main source of water-supply to the crop besides rainfall is that due to the rise in the rivers to inundation level. Large irrigation works are also being established in recent years. The average rainfall is about 40 to 60 inches and a rice crop is said to require about 70-acre inches.

Besides the hill rice which is grown in cleared jungles on the hills, the wet rices are both broadcast and transplanted. There are varieties differing in duration from early-75 days, to late-7 months. Plantings begin in May and may continue until October in Central and North Siam while in South Siam it extends from July to December. The general harvest comes in any time between September and May. The average yield for the whole country ranges from 1,300 lb. to 1,600 lb. of grain per acre and the recorded maximum yields have been up to 3,500 lb. The floating rice grown in flooded areas is a common feature of Siam and occupies a large area.

The conditions of rice growing in Indo-China are not very different from those of Siam. As in Siam the cultivation of floating rice is also a special feature of Indo-China. The land is ploughed dry as for dry rice and the seed may be either broadcast or drilled. It may even be mixed with maize which is planted a fortnight before rice so as to be ready for harvest in advance of

the floods. For the first few months there is very little growth in the rice plants but as the flooding begins they grow rapidly and keep pace with the rise in water-level.

Like Siam, Indo-China is also a large rice exporting country and the whole export is in the shape of well-milled white rice, whole and broken. The ryots' produce being usually a mixture of varieties varying in size, there is a large amount of breakage in milling and the improvement in the quality of the grain has remained an even more important problem than improvement in acre yields. To get over the difficulty of breakage in milling the produce of the cultivators is put through a mechanical grader to separate the grains of different sizes. The particular type desired is retained and distributed to the people as seed.

Java.—Java has probably the best-developed irrigation system for growing rice. The rice soils here are comparatively more fertile and are also suitable for dry crops. On most lands rice is regularly rotated with maize, soyabean, groundnut, tobacco and sugarcane. Sugarcane is grown on a large scale on rice land rented from native cultivators once in three or four years.

Rice in Java is mainly transplanted. The seed-beds are usually kept rather dry and not heavily fertilised, the belief being that the seedlings will stand transplanting better after such treatment. With regard to manuring rice in Java, phosphatic fertilisers have been found to give large increase in yields on many soils, but the use of fertilisers is, however, limited due to the general poverty of the cultivator. The average yield in Java is about 2,000 lb. of grain per acre.

Ceylon.—The methods of cultivation of rice in Ceylon are practically the same as in Madras. The average acre yield is very low, less than 1,000 lb. grain, and even with a little over eight lakhs of acres under rice, the output is hardly enough to meet even half the requirements. The deficits are met to a small extent from India proper, but mainly from Burma. Rice here is chiefly cultivated in the low country but considerable areas are also grown at elevations of two to four thousand feet above sea-level. Irrigation water is generally utilised both to supplement and in the dry season to replace direct rainfall. Even in the wetter parts of the island the run-off from land adjoining the rice fields is utilised. Owing to risk of floods in the wet season large areas are cultivated under irrigation during the dry season.

Rice is mostly broadcast though as a result of the propaganda by the Agricultural Department, the transplanted area is gradually increasing. One serious difficulty with regard to the extension of the practice of transplanting is the dearth of labour.

Some of the other Asiatic countries which grow rice to a small extent are Russian Turkestan, Persia and Mesopotamia.

Rice in Europe.—Rice cultivation in Europe is practically confined to the Mediterranean Coast, Spain and Italy being the two countries which grow rice on a large scale. The total area under rice in Europe does not probably exceed six lakhs of acres, and is not more than the area in one district of Madras, say, Chingleput. But the average acre yields of rice in Spain and Italy are very much higher than in India or elsewhere.

Spain.—The area under rice is about a lakh of acres and the greater part of this is permanent rice land unlike in Italy and Greece where rice is rotated with other crops. The whole area is supplied by a magnificent system of irrigation canals. The cultivation of rice in Spain has been brought to a higher pitch of perfection than anywhere else in the world. Unlike in Madras where dry cultivation of fields has proved harmful, in Spain the land is ploughed and harrowed well in winter (January). Water is let into the fields in May and the crop is transplanted with seedlings raised earlier. Seed-beds receive a good dose of green manure and fertilisers. Transplanting is done in three to four inches of water, clumps of three to five plants being planted eight to ten inches apart. In June the water is run off for a few days and the fields are weeded. The crop is harvested in September-October with sickles as in Madras.

The fields are generally heavily manured, each acre getting about two hundred weights of sulphate of ammonia, three hundredweights of super-phosphate and half a hundredweight of potassium sulphate. Half this quantity is applied just before planting and half, a month later at the time of weeding.

The average acre yield in Spain is over 5,000 lb. of grain, the highest in the world. Apart from the general fertility of the fields the very much higher yields of Spain than in Madras may be attributed partly to the better methods of preparing the lands for rice and partly to the intensive manuring.

Italy.—The area under rice in Italy is about four lakhs of acres. About eighty per cent. of this area is broadcast by hand, about ten per cent. drilled by machines and ten per cent. transplanted.

One chief feature of the Italian rice area is that the fields are beautifully levelled and laid in sizes of twenty to thirty acres each. Tractors are used for ploughing and harrowing. When the soil is in good condition water is let in and the soil is well stirred by means of a puddling machine drawn by a tractor or horses and then levelled by hand implements. On large farms drills are used for sowing and here the later thinning is also done by horse-drawn machines. Due to the high cost of labour, transplanting is not practised but suitable transplanting machines have been designed and are under trial.

The main rice-growing area adopts a seven-year rotation, namely, wheat, two years meadow land and four years rice. Rice occupies only a portion of each holding, the rest of the area being devoted to other crops among which, clover dominates which permits the farmer to maintain many work animals and milch cows.

The manuring of rice fields is also very intensive. Farm-yard manure forms the basal manure. When this is not applied fertilisers to the extent of 6 cwt. of super-phosphate and 2 cwt. of potassium sulphate are applied per acre. If found necessary, this is again supplemented by 1 cwt. of ammonium sulphate at the time of weeding. Leguminous crops, chiefly clover, is first sown in the fields and ploughed in before rice is planted.

The fields are not generally flooded and water is allowed to flow gently from the main channels through small distributing channels taken at every six yards. The distribution of water is left entirely in the hands of rice-growers who pay the charges to an association which in turn pays the Government. There are also canals owned by private owners which is unique in Italy. In spite of the apparent economy in the use of irrigation water, from the figures given by Tempany, it would appear that the actual quantity of water used by a five-months' crop in Italy is about 100-acre inches, which is more than what is used in Madras for a crop of similar duration. Twice during the growth of the crop water is cut off and the fields allowed to dry up for a few days when irrigation is resumed. This practice has one serious dis-advantage in that it encourages weed growth and in fact weeding is one of the most expensive items in the cost of growing rice in Italy.

While harvesting is entirely done by hand, threshing is done by machines worked by electricity. The cultivator invariably sells his produce as milled rice and not as grain as in Madras.

The average acre-yield in Italy is about 3,500 to 4,000 lb. grain. The cost of cultivation would appear to be about Rs. 350 to Rs. 400 per acre and at the present price an acre of rice would bring in a profit of only about Rs. 70.

Rice is also grown to some extent in Bulgaria and Greece and the season for rice is practically the same as for Spain and Italy. One special feature of rice culture in Europe is that the produce is invariably dried artificially with hot air machines, there being no sufficient sun to dry the grain as is done in India.

Rice in America—United States.—The three main rice-producing regions of the United States of America are (1) the broad prairie region of south-western Louisiana and south-eastern Texas, (2) the prairie region of eastern Arkansas and (3) the interior valleys of California. The water for irrigation is obtained mostly by the use of powerful pumps pumping water from either sluggish

streams or deep wells. There is also a certain amount of irrigation from rivers by gravitational flow as in California. In contrast with rice culture in the orient, where the entire operations are done by manual labour, in America, practically everything is done by machinery.

The preparation of the land is all done by powerful tractors. The land is first ploughed in winter to a depth of six to seven inches and allowed to weather. It is ploughed again in early spring, disked and harrowed immediately. Rice is either sown with a grain drill or broadcast with an ' endgate seeder.' Recently aeroplanes have also been used to sow rice in water. Two inches is considered a good depth to sow the seed in, if drilled. The sowing is usually done in May and a seed rate of 100 to 150 lb. is used per acre.

Generally irrigation is seldom used to germinate the seed. When, however, irrigation is required for germination great care is taken to drain the water off after 48 hours. The irrigation usually starts when the plants have reached a height of six to eight inches and the water which is now given to a depth of one or two inches is gradually increased until the maximum depth of five inches is obtained. This depth is maintained until sometime before harvest. The water is drained off about two weeks before harvest so that the land will get dry enough to support harvesting machines. The rice crop in America is stated to require about 48-acre inches of water, of which about 20 inches are contributed by rains. The cost of pumping water from deep wells of say 100 feet, is said to work out at Rs. 25 to Rs. 32 per acre.

The crop is cut when the grains in the lower portions of the panicle have not quite hardened as this is supposed to give the best quality rice. The harvesting is done by twine binder and the sheaves are shocked in the field for a period of seven to fourteen days when the grain and straw gradually dry. The sheaves are then threshed and the produce bagged and despatched immediately to the warehouse.

As regards manuring, under ordinary conditions, best results have been obtained only with the ploughing in of a leguminous crop. Without an adequate supply of organic matter to the soil, the use of fertilizers gives only a temporary benefit and there is even ultimate harm done to the soil. The growing of soyabean in rotation with rice is advocated. The soyabean crop not only helps in the control of weeds in the rice fields, but the plants after the beans are removed, when ploughed in, form an excellent organic manure to the following rice crop. Though cotton is grown in rotation with rice in well-drained soils, in typical rice soils no other crop can be successfully grown except soyabean.

Rice milling in America has been highly developed and the American rices, coming into the European markets, are such a highly finished product that they cost much more than rice from

any other country. The rice has a pearly attractive appearance and is graded absolutely to a uniform size.

The rice area in the United States of America varies from eight to nine lakhs of acres and the average acre-yield is about 2,500 lb. of grain. The cost of production is roughly seventy to eighty rupees per acre while the value of the average produce at the present price comes to about Rs. 100 leaving a profit of about Rs. 25 per acre.

Rice is also grown in considerable quantities in parts of Central and South America, the Republic of Brazil having an exportable surplus.

British Guiana.—Rice culture is an important industry of British Guiana, occupying about 30 per cent. of the total area under cultivation. The average acre-yields are nearly double those of India. Since there is a great possibility of both extending the area under rice and improving the yields, this country may become an important factor in rice trade. All the rice produced is converted into par-boiled rice for local consumption as well as for export.

Rice in Africa.—There is an area of over three lakhs of acres under rice in lower Egypt dependent on Nile irrigation. The average acre-yield of Egypt (over 3,000 lb. grain) is very much higher than in India and compares favourably with those of Japan though the crop is not generally fertilised nor transplanted. Throughout tropical Africa some rice is grown wherever there is water but nowhere it is produced in quantities to be of any importance commercially.

Rice in Australia.—The rice area in New South Wales under the Murrumbridge irrigation has recently been increasing rapidly. but the production has still not exceeded the consumption. By the introduction of rice cultivation, lands which were unfit for any crop previously have now begun to produce remunerative crops of wheat and oats.

The problem of weed control is rather serious and suitable rotations are followed to meet it. Rice is sown in October and harvested in April-May. The land is winter fallowed and an early maturing variety of wheat is sown in May and harvested in December. A short fallow follows this when a winter leguminous crop is sown and grazed off by sheep. The land is ploughed shallow in August and the rice is planted in October.

The seed is always broadcast at about 90 to 100 lb. per acre. So far there has not been followed any system of fertilising the rice crop. The harvesting and threshing is all done by machinery. The 'Header' deals with harvesting, threshing and bagging of the produce all in one operation.

The cost of cultivating rice per acre comes to about Rs. 140 to 150 which is about the cost of one ton of grain locally.

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Station.	From	To
Aduturai	1926–27	1933–34
Anakapalle	1914–15	1933–34
Berhampur	1932–33	1934–35
Coimbatore Central Farm ...	1909–10	1933–34
Coimbatore Paddy Breeding Station	1915–16	1934–35
Maruteru	1926–27	1934–35
Palur	1905–06	1933–34
Pattambi	1926–27	1934–35
Samalkota	1906–07	1933–34
Taliparamba	1907–08	1933–34

Paddy surveys in Madras Presidency done by the Paddy Specialist's staff. (Unpublished.)

Chingleput.
Coimbatore.
Godavari.
Kistna.
Madura.
Malabar.
South Arcot.
South Kanara.
Tanjore.
Tinnevelly.

APPENDIX A

Strains already evolved in Madras

Coimbatore strains

GEB. 24 was the first successful strain and was a selection from a bulk crop of *konamani* grown on the Central Farm in 1913–14. Evidences are accumulating that it must have arisen first as a mutation. This strain is a short duration *samba* variety, very popular in this Presidency on account of its high quality of table rice. It can be grown under varied conditions. It matures in about 150 days when sown in July-August but the duration will be extended or reduced according to the sowings being made earlier to or later than July-August. It gives an average yield of 3,600 lb. (transplanted) per acre and with intensive cultivation a maximum of 5,000 lb. per acre has also been obtained. Profuse tillering, fine size of grain, hard rice taking a good polish, non-shedding even when dead ripe, resistance to fungus diseases and drought, high proportion of rice to paddy, are some of the qualities for which GEB. 24 has a reputation. It is easily distinguishable by its open panicle on a slender axis and a horizontal flag leaf. It does best on a fairly light soil with good drainage. It is known as '*kitchili samba*' round about Coimbatore. It is grown all through the Province and has entirely replaced the local varieties in certain tracts. It is the chief variety of rice in the adjoining Mysore State.

Co. 1 is a selection from a natural cross in GEB. 24. While possessing several of the good qualities of GEB. 24, the quality of rice is not quite so good as GEB. 24, and the grain is a little coarser. It matures in 160 days and gives an average yield of 3,645 lb. cleaned grain on the Central Farm, Coimbatore. The straw is also coarser than that of GEB. 24. It has recorded an average increase of 20 per cent. over GEB. 24. Like GEB. 24 it responds to intensive treatments and yields of over 5,000 lb. per acre have been obtained in Coimbatore with this strain.

The spread is far more limited. It is very popular round about Coimbatore and has been well spoken of in Karur, Kulittalai and Musiri taluks of Trichinopoly where it has the reputation of being particularly suited to a precarious water-supply. It comes up well in Nandyal and Kollengode giving increased yields over local varieties.

Co. 2 is a selection from *poombalai* or *karthiga samba* from Tinnevelly district, specially suited for late sowings in October or November. In Coimbatore it matures in 157 days and gives an average of 3,900 lb. of threshed grain per acre. The quality is fairly good and straw quite up to average. It has recorded an average increase of 8 per cent. over local bulk seed.

This is the most popular strain in the Fourth Circle being suitable for the late *samba* season. It is particularly popular in North Arcot, Madurantakam in Chingleput and Tindivanam in South Arcot. It is liked by ryots in Tanjore and Karur and is well reported of from parts of Tinnevelly and Ramnad districts. In Gobichettipalaiyam taluk it has given 12 per cent. more yield than local *sadai samba*.

Co. 3 is a selection from *tulukka samba* of Coimbatore. It matures in 160 days and gives an average acre yield of 4,050 lb. It has recorded an average increase of 9 per cent. over local bulk seed. It is very popular round Coimbatore where it has largely replaced *sadai samba*. In Gobichettipalaiyam taluk this has given 14 per cent. increase over *sadai samba*. It is well known in Tenali where the fertile soils produce yields up to 3,400 lb. It has been largely grown in the Second Circle. It has done well as a semi-dry crop in parts of Chingleput district also. It is also successfully grown as a second crop in Malabar and South Kanara districts.

Co. 4 is a selection from *anaikomban* of Gobichettipalaiyam. It matures in 192 days from sowing. The grain size is fairly coarse and has a reddish brown glume but the rice is of white colour of average quality. The straw is thick and coarse. It has recorded an increase of 12 per cent. over local bulk seed and an average yield of 3,800 lb. per acre. It is very popular in Gobichettipalaiyam and Mettupalaiyam taluks of Coimbatore. A few trial plots in South Kanara have given very satisfactory results.

Co. 5 is a selection from *chinnasamba* of Coimbatore. It matures in 164 days from sowing. It responds well to manuring with profuse tillering. The earheads are thick and long and the grains well filled. It has recorded an average increase of 12 per cent. over local bulk seed and has given an yield of 4,790 lb. per acre. It is popular in Gobichettipalaiyam and has recently spread in the Second Circle, particularly at Bezwada and Kondapalli in Kistna district and some villages in Nellore district. This has given good profits to ryots at Cuddapah, Proddatur, Markapur and Cumbum in the Third Circle.

Co. 6 is a selection from *sadai samba* of Coimbatore and takes 176 days to mature. It has recorded an increase of 10 per cent. over local bulk seed and gives an average yield of 3,900 lb. per acre. The grain is of medium size, slightly broader than Co. 3. This is largely grown round about Coimbatore but is not so well known outside.

Co. 7 is a selection from *sadai samba* of Gobichettipalaiyam. It has profuse tillering and is a heavy yielder of grain and straw. It matures in 157 days and has yielded 4,157 lb. per acre. It has recorded an average increase of 10 per cent. over local bulk seed. This is becoming popular in the districts of Second and Fifth Circles. It has been found to be very promising in Kavali and is likely to replace the local *molakolakulu*. It has been introduced with success in parts of Karur and Perambalur taluks in Fifth Circle.

Co. 8 is a selection from *anaikomban*, the *pishanam* variety of Tinnevelly district. The crop matures in 190 days, yielding a grain approaching that of GEB. 24 in fineness. The average yield is about 3,000 lb. per acre. On a six years' average, this strain has been found to give 17 per cent. more yield than local bulk seed under Coimbatore conditions. This is now spreading in parts of Tinnevelly district.

Co. 9 is a selection from *Tinnevelly kar*, a short duration first-crop variety. The crop matures in 116 days yielding about 3,000 lb. of grain per acre. On a four years' trial at Coimbatore this strain has given a 14 per cent. increase over local bulk seed. The rice is red and the grain is slightly coarse. The grain has a dull straw colour with brownish tinge in the furrows.

Co. 10 is a selection from Gobichettipalaiyam *kar*, a short duration first-crop variety grown extensively in Gobichettipalaiyam taluk of Coimbatore district. The crop matures in 125 days, yielding about 2,500 lb. of grain per acre. This has recorded an increase of 17 per cent. over local bulk seed. The grain is coarse and rice white and is reported to be popular for the preparation of puffed rice.

Co. 11 is a selection of *Gobichettipalaiyam ayyan samba*, a long duration variety of Gobichettipalaiyam tract noted for its fine rice. The grain is thin, long and slightly beaked. It matures in 185 days and is valued for its fine quality. This has recorded an average increase of 13 per cent. over the local bulk seed.

Aduturai strains

Adt. 1 is a selection from *red sirumani*, an important variety of Tanjore. The selection was originally made at Manganallur. The strain gives an increased yield of 16 per cent. over the ryots' seed. It matures in 175 days from sowing to harvest. The average yield is 2,500 lb. per acre. The strain is very popular in the Fifth Circle and has spread extensively in the eastern part of the Cauvery delta, particularly in Shiyali, Mayavaram, Nannilam and Negapatam taluks. It is also reported to have done well in Chidambaram and Cuddalore taluks of South Arcot district. It is grown to a small extent in the Second Circle. The name *red sirumani* is due to the brownish furrows on the grain when ripe.

Adt. 2 is a strain, again the result of selection work started at Mangarnallur farm on the ryots' crop of white *sirumani*. The crop matures in 165 days and gives an increased yield of 10 per cent. over that of ryots' bulk. The average grain yield is 2,400 lb. per acre. The paddy consists of bright straw coloured small round grains and is highly valued by richer classes in Tanjore district as good table rice. The par-boiled rice prepared out of this has a special market in Ceylon. This strain has extensively spread in the eastern half of Tanjore delta and is also popular in parts of Fourth Circle.

Adt. 3 is an early maturing strain of Tanjore *kuruvai* paddy. It matures in 95 days and gives an average yield of 2,000 lb. of grain per acre. The grain has dark brown furrows and the rice though white is rather coarse. The strain is popular because of its early maturity and has spread widely in Tanjore and Trichinopoly districts. It has recently spread to other tracts of the province as well wherever a short maturing variety was in need as in parts of Vizagapatam and Bellary districts. The ripe grain because of its brown furrows cannot be easily distinguished from *nellore samba*.

Adt. 4 is an improved strain of Tanjore *kuruvai* paddy. This takes a week more than Adt. 3 and gives an increased yield of 10 per cent. over the ryots' seed. This strain has a slight tendency to exhibit unsetting but the yields are not appreciably affected on that account. This gives an average yield of 2,300 lb. grain per acre. The ripe grain has brownish furrows but not so dark as in Adt. 3.

Adt. 5 is a selection from *nellore samba* grown extensively in Tanjore and Trichinopoly districts. It matures in 185 days from sowing to harvest. This gives an increased yield of 25 per cent. over local bulk. The average yield is 2,500 lb. grain per acre. This is popular in the western half of Tanjore delta. In Nellore it was found to be better than local *molakalakulu*. This has also spread in parts of Tinnevelly district as a *pishanam* crop. The grain has dark brown furrows and the rice is good white.

Adt. 6 is a strain of *red ottadan*, from the initial selection made at Mangarnallur. The strain gives an increased yield of 15 per cent. over the local seed and matures in 220 days. This strain when grown as 'udu' mixed with *kuruvai* gives an average yield of 1,400 lb. per acre. The ripe grain has a uniform reddish brown husk and hence the name.

Adt. 7 is another selected strain of *ottadan* and differs from Adt. 6 only in having ordinary straw coloured glumes. The crop matures in 220 days and gives an increased yield of 13 per cent. over local seed. The average grain yield of the strain when grown as 'udu' is 1,400 lb. per acre. The grain has occasionally a short awn attached to it.

Adt. 8 is an early maturing hybrid strain of *white sirumani* type of grain obtained from the progenies of a cross between Adt. 2 and *molagu samba*. It is definitely a fortnight earlier than Adt. 2 and therefore can be grown for catching the Ceylon market. It can be grown as a second-crop variety instead of Adt. 2, in places where there is water scarcity at the end of second-crop season. It has recorded the same yield as Adt. 2 and in certain cases has even exceeded it.

Adt. 9 is a strain from *poonkar* variety and has given on an average 13 per cent. increased yield over its bulk. In the district trial conducted at Lalgudi, it gave a 31 per cent. increased yield. Wherever water is received early it is grown in place of *kuruvai* and records a very much higher yield of both grain and straw than *kuruvai*. It matures in 112 days from sowing and gives an average yield of 2,500 lb. per acre.

Adt. 10 is a selection from *korangu samba* variety which is grown in about 4 lakhs of acres in the eastern half of the Cauvery delta. This strain gives a 10 per cent. increased yield over the local seed. The grain has dark brown furrows. It matures in 166 days and gives an average yield of 2,500 lb. per acre.

Adt. 11 is a fine grained strain from *nellore samba* (AEB. 65) and has given on an average 7 per cent. increase over the bulk. This strain will replace AEB. 65, as it has a much more uniform stand being the

progeny of a single plant. It has mostly spread in Trichinopoly, Periyar tract and Tinnevelly. Recently it has been introduced into Nellore district also where it does better than the local *molakalakulu*. It matures in 176 days from sowing and gives an average yield of 2,500 lb. per acre.

Maruter strains

Mtu. 1 is a strain from *bontha akkullu*, a white riced variety grown over 40—50 per cent. of the area in Godavari delta and portions of Kistna delta as well under a variety of conditions, from the precarious uplands to the saline and submergeable coastal areas. Its normal flowering time is the third week of October irrespective of the time of sowing or planting within broad limits. It takes about 185 days from sowing to maturity. The average yield varies from 2,800—3,700 lb. per acre. The six years' average increase over ryots' bulk is 20 per cent. at the Maruter station. The grain has a rich brown colour.

Mtu. 2 is a selection from *potti akkullu*, a variety with rather slower initial growth found suitable to rich lands that usually suffer from rank growth and premature lodging. Six years' average increase over ryots' bulk is 16 per cent. The rice is white. Normally it flowers during the third week of October, slightly later than Mtu. 1. It takes about 185 days to mature, from sowing. The average yield ranges from 2,800—3,500 lb. per acre. The grain is rich brown in colour like Mtu. 1.

Mtu. 3 is a strain from *basangi*, a variety confined to about 10 per cent. of the area in the higher portions of the delta. The rice is white and the grain is short and plump compared to the local seed. This is particularly suited to areas of poor fertility and where planting is done late. It flowers generally during the fourth week of September. It matures in about 160 days from sowing. The average yield varies from 3,500—4,500 lb. per acre. The average increase is 12 per cent. over the ryots' bulk at the Maruter station.

Mtu. 4 is another selection in *pedda basangi*. It is later in duration than *potti basangi* by a week. It has been found useful to areas of average fertility planted late. This has been noted to stand indifferent water-supply during its vegetative growth. The rice is white and the grain size is narrower than local seed. It has recorded an average increase of 9 per cent over local seed. The average yield varies from 3,200—3,800 lb. per acre.

Mtu. 5 is a selection from *bontha krishnakatukalu*, a popular variety of West Godavari district covering 30—40 per cent. of the area in the Western delta. Due to the fineness of the grain it fetches better price. It has recorded an average increase of 10 per cent. over the ryots' bulk. It generally flowers towards the last week of October. It matures in about 195 days after sowing. The average yield varies from 2,800—3,400 lb. per acre. The grain has a characteristic dark purple tip and end.

Mtu. 6 is a selection from *potti atragada*, a variety chiefly cultivated in about 5 per cent. of the area, confined mostly to the lower reaches of the Godavari delta, where water does not drain off early for harvest. It has given an average increase of 16 per cent. over ryots' bulk. It flowers during the end of October. It matures in about 200 days after sowing. The average yield ranges from 2,800—3,000 lb. per acre. The grain has a rich brown colour.

Mtu. 7 is a selection from *gutti kusuma*, a variety grown over 40—50 per cent. of the area in Kistna and Guntur deltas. It has recorded an average increase of 16 per cent. over ryots' bulk. It matures in about 208 days after sowing and generally flowers during the second week of November, later than the local *kusuma* by about a week and it is not subject to lodging trouble. It gives bold, well-filled, good white rice. The average yield ranges between 3,400—3,700 lb. per acre.

Mtu. 8 is a selection from *vankisannam* also known as *delhi bhogum* chiefly cultivated in about 15—20 per cent. of the area in Kistna and Guntur deltas, specially confined to the higher delta and well-drained soils. It

has recorded an average increase of 10 per cent. over local seed. It matures in about 205 days after sowing and generally flowers during the end of the first week in November. The maximum grain yield obtained in one of the trial plots at Duggirala was 3,400 lb. per acre. The crop raised from this strain has a characteristic dark green appearance during the early vegetative growth and an erect leaf during the flowering and ripening stages. The ripe grain is uniformly reddish brown and is noted for its fineness and translucent rice. The variety usually exhibits a certain amount of unsetting of grains which may get worse in seasons when there are rains during the flowering period.

Pattambi strains

Ptb. 1 is a strain of *aryan*, an important first-crop variety grown in Walluvanad, Ernad and Ponnani taluks. It matures in 145 days. Sown in the second week of May, it flowers about the first week of September. It has consistently given 15·8 per cent. increase over the local bulk. The grain is brown in colour and has dark furrows on the husk. The rice is red. The average yield is 2,961 lb. per acre.

Ptb. 2 is a strain from *ponnaryan* generally grown in high level single-crop lands called *palliyal* in Walluvanad and Ponnani taluks. The duration of the crop is 135 days from sowing. Sown early in June, this flowers by the third week of September. The grain is golden brown in colour, and the rice is red. Average increase over ryots' bulk in four years' test is 15·4 per cent. The average yield is 2,140 lb. per acre.

Ptb. 3 is a strain from *eravapandy*, the earliest of the second-crop varieties with a duration of 128 days, chiefly grown in Walluvanad and Ponnani taluks. Sown in the second week of September, this flowers by the middle of December. Rice is red. Four years' average increase over ryots' bulk is 8·3 per cent. The average yield is 1,850 lb. per acre.

Ptb. 4 is a strain from *vellari*, a red riced second-crop variety grown in Ernad and Walluvanad taluks. The duration is 140 days from sowing. Sown early in September, it flowers towards the close of December. Four years' average increase over local bulk is 22·6 per cent. The average yield is 2,060 lb. per acre.

Ptb. 5 is a strain from *veluthariikayama*, a red riced first-crop variety of 140 days' duration, chiefly grown in Walluvanad, Ernad and Ponnar taluks. Sown by the middle of May, this flowers by the first week of September. During the four years' test, it has recorded an average increase of 13·7 per cent. over the local bulk. The average yield is 2,340 lb. per acre.

Ptb. 6 is a selection from *athikraya*, a major second-crop variety of South Kanara. The rice is red and the duration of the crop is 145 days from sowing to harvest. Sown early in September, this flowers by the end of December. Four years' increase over control is 18 per cent. The grain has a uniform dark brown (dirty) colour on the husk. The average yield is 2,160 lb. per acre.

Ptb. 7 is a strain isolated from *parambuvattan*, a first-crop red riced awned variety, grown in palliyals or single-crop lands in Walluvanad and Ponnani taluks. This variety is known for its adaptability to irregular supply of water during the growing period and for its slight tolerance to saline conditions in the coastal area. The crop matures in 120 days (sowing to harvest). This strain whose rice is red and whose glume ripens black with full awns maintained an average increase of 13 per cent. over the local seed. Under favourable conditions the strain recorded an increase of 25 per cent. in the district trial. Its yield per acre varies between 1,400 to 1,800 lb. according to the season, rainfall and soil fertility.

Ptb. 8 is *chuvannari thavalakkannan*, a strain isolated from local *thavalakkannan* bulk, a first-crop variety of 135 days' duration generally cultivated in the double-crop wet lands in the districts of Malabar and to some extent in South Kanara. The local crop is a mixture of both red and white rice. This strain recorded an average increase of 16·9 per cent. over six years' trial. The special feature of the strain is that it matures a week earlier than the local. This would enable the early commencement

of the cultivation of the following second crop. The glume colour of the strain is straw with purple tip slightly spread. Its rice is red and hence the name of *chuvannari* (red rice) is given to the strain to distinguish it from the white rice strain Ptb. 9.

Ptb. 9 is *veluthari thavalakkannan*, a white rice strain isolated from a ryot's bulk crop of *thavalakkannan* grown in the first-crop season in double-crop lands. It is of the same duration as that of the local bulk. It has an erect tall growing habit and is also noticed to be comparatively free from lodging. The strain maintained an average increase of 13·6 per cent. over the standard. Its yield varies from 2,000 lb. to 2,400 lb. per acre.

Ptb. 10 is a strain from *thekkan cheera*, a short duration variety of about 100 days grown in all the three seasons in the Malabar district. Monthly planting trials for three years at the Agricultural Research Station, Pattambi, have revealed its fitness for cultivation throughout the year as its flowering time is not season fixed. However, the crop during the *punja* season (February to March) is at its best. This strain maintained an average increase of 10 and 8 per cent. during the first and third-crop seasons, respectively. Its yield per acre varies between 1,500 lb. to 1,800 lb. Its rice is red and is preferred by the local people for their home consumption.

APPENDIX B

A list of varieties of rice recognized in the markets in the Madras Presidency

Classification of varieties.

District	Coarse	Medium and fine
Ganjam district—	Boroponko, Panchakolia—Imported from Orissa, "Rasulu"—Mixture of varieties.	Rathanachudi, Byyahunda, Macha—Imported from Orissa, Gunupur Sannam, class I (grown in the Agency), Gunupur Sannam, class II (grown in the Plains), GEB. 24.
Vizagapatam district—	Ramagada, Mypali	Gunupur Sannam, Navakoti Sannam, Byyahunda, GEB. 24.
East Godavari district—	First crop varieties—Basangi, Rasangi,[1] Punasa Konamani, Konamani; second crop varieties—Nallarlu, Garikisannavari.	Krishnakatukullu (Mtu. 5), GEB. 24.
West Godavari district—	First crop varieties—Basangi[1] (Mtu. 3 and 4), Potti Atragada (Mtu. 6), Konamani; second crop varieties—Garikisannavari, Nallarlu.	Akkullu (Mtu. 1 and 2), Krishnakatukullu (Mtu. 5), GEB. 24.
Kistna district—	Kusuma (Mtu. 8), Konamani ..	Pala Akkullu (Mtu. 1), Pedha Atragada, Ramasagaralu, Vankisannam or Delhi Bogham (Mtu. 7), GEB. 24.
Guntur district—	Kusuma (Mtu. 8), Konamani ..	Pala Akkullu (Mtu. 1), Pedha Atragada. Ramasagaralu, Vankisannam or Delhi Bogham (Mtu. 7), GEB. 24, Molagulukulu,
Nellore district—	Vadansamba, Redkesari, Nallavadlu.	Molagulukulu[2] (Adt. 11), GEB. 24, Co. 2 Pishanam.
Chingleput district—	Vadansamba, Kar, Manavari ..	Sirumani, Chinnasamba, GEB. 24, Co. 2.
South Arcot district—	Vadansamba, Muthusamba, Garudansamba, Mottai kar, Swarnavari,[3] Kuruvai (Adt. 3).	Kothamalli samba or white sirumani (Adt. 2), red sirumani (Adt. 1), Co. 2, Co. 3, GEB. 24.
Tanjore district—	Kuruvai (Adt. 3 and 4), Poonkar (Adt. 9). Vadansamba, Kathuvanam, Kattaisambalai or Korangusamba (Adt. 10), Nellore samba[2] (Adt. 5 and 11), Ottadan (Adt. 6 and 7).	White sirumani (Adt. 1), red sirumani (Adt. 2).
Trichinopoly district—	Sarapalli,[3] Kuruvai (Adt. 3) and Poonkar.	Sadai samba, Nellore samba (Adt. 11.) Co, 1, Co. 2, Co. 3 and GEB. 24.

Coarse	Medium and fine
Madura district—	
Mattai Nellu, Vallaikattai, Vari Garudansamba, Manavari and Milagi.	Nellore Samba or Arai samba [2] (Adt. 5 and 11), Peria samba, Poovansamba, Sirumanian and GEB. 24.
Tinnevelly district—	
Kar samba (Co. 9), Pulithiparati Kuruvai kalyan, Arikkiravari and Veethivadangan.	Sembali or Nellore samba (Adt. 5 and 11), Karthigaisamba or Erakkusamba Anaikomban (Co. 8). Sendinayagam and Vallai samba.
Ramnad district—	
Manavari, Vallaikattai and Milagi.	Karthigai samba or Poombalai (Co. 2), Anakomban (Co. 8) and Muthuvalai.
North Arcot district—	
Surnavari,[3] Vallakar, Chitrakali, Manavari, Manakattai and Vadansamba.	Chinna samba, GEB. 24, Sadai samba, Palansamba and Co. 2.
Chittoor district—	
Tellasannavadlu, Pichia sannavadlu,[3] Tellakar, Mottaikar for alkaline lands, Manakattai, Nalla vadlu and Bairi vadlu.	Chinna samba, Palan samba and GEB. 24.
Anantapur district—	
Sannavadlu, Kasari, Boruguvadlu and Muduganti vadlu.	GEB. 24.
Bellary district—	
Sannavadlu, first crop, Mulluvadlu, second crop and Sepoi.	GEB. 24 has replaced the local varieties to a great extent in the paddy areas of this district.
Kurnool district—	
Lavuvadlu, Venkalu and Budama.	Bangaruthegalu, GEB. 24 and Pasapasandalu.
Cuddapah district—	
Kesari, Buddasankalu and Pottinallavadlu.	Nellore Pishanam [2] or Molagulukulu (Adt. 11), Pidikedu Pishanam and Pattadisamba.
Salem district—	
Vallaikar (Adt. 3 and 4), Kar and Manavari.	GEB. 24, Sadai samba, Chinna samba, Gundan samba, Co. 2, Co. 3 and Pillansamba.
Coimbatore district—	
Vallaikar and Anaikomban (Co. 4).	Nellore samba (Adt. 5 and 11) Sadai samba, Chinna samba, Rangoon samba, Co. 1, Co. 2, Co. 3, Co. 5, Co. 6, Co. 7 and GEB. 24.
Malabar district—	
Tekkan cheera, Kayama, Chettani, Aryan and Tavalakannan.	GEB. 24 and Anaikomban.
South Kanara district—	
Kayama, Guddu and Athikrayi..	Mascati, Jeerasalae, Gangullu Sannam, GEB. 24, Co. 2 and Co. 3.

N.B.—Co. 1, 2, etc., strains evolved at the Paddy Breeding Station, Coimbatore.
Adt. 1, 2, etc., strains evolved at the Agricultural Research Station, Aduturai.
Mtu. 1 to 8, strains evolved at the Agricultural Research Station Maruteru.
Nos. 1, 2, 3, etc., against the names of the varieties refer to synonyms of the same variety.

APPENDIX C

Area in acres under rice (irrigated and unirrigated) from 1918–35 in the different districts in the Madras Presidency.

Units—Thousands.

—	1918-19.	1919-20.	1920-21.	1921-22.	1922-23.	1923-24.	1924-25.	1925-26.	1926-27.	1927-28.	1928-29.	1929-30.	1930-31.	1931-32.	1932-33.	1933-34.	1934-35
Ganjam	1,183	1,205	1,085	1,100	1,086	1,104	1,224	1,239	1,152	1,181	1,141	1,111	1,106	1,012	1,058	1,058	1,077
Vizagapatam ..	1,049	1,089	887	963	915	1,081	1,144	1,160	1,155	1,166	1,187	1,165	1,117	1,127	1,117	1,113	1,136
East Godavari ..	576	607	440	540	480	514	560	603	635	620	637	595	587	666	653	633	683
West Godavari ..	..	..	..	..	..	..	631	662	681	696	658	665	662	685	684	675	677
Kistna	1,145	1,201	1,064	1,115	1,108	1,104	526	531	538	556	563	569	558	570	583	577	567
Guntur	393	351	355	381	378	348	369	385	400	386	391	393	394	401	404	396	395
Kurnool	74	81	57	72	60	57	53	64	58	68	62	46	65	70	60	71	71
Bellary	37	44	34	43	32	26	29	31	28	27	28	30	28	30	37	41	33
Anantapur	89	164	65	111	76	36	84	69	83	90	73	111	134	66	103	138	42
Cuddapah	90	130	101	133	100	71	100	125	94	85	94	104	141	111	74	100	70
Nellore	416	473	394	400	397	356	392	466	350	390	373	396	466	429	364	422	376
Chingleput	586	678	692	663	732	643	652	731	638	614	686	709	722	752	725	725	667
South Arcot	443	558	596	547	592	544	523	557	539	525	575	598	594	613	627	610	556
Chittoor	140	209	177	190	190	137	172	176	168	176	183	196	302	247	191	205	178
North Arcot	329	514	525	458	497	343	387	462	377	383	449	423	537	585	528	488	436
Salem	127	190	211	221	205	121	115	92	93	104	94	113	171	144	186	202	154
Coimbatore	88	108	106	109	109	103	104	100	101	101	97	100	118	106	117	122	102
Trichinopoly	257	322	348	327	336	287	249	238	250	251	248	271	305	298	335	337	288
Tanjore	983	1,126	1,133	1,108	1,131	1,107	1,052	1,097	1,103	1,091	1,082	1,117	1,099	1,086	1,099	1,118	1,123
Madura	308	334	366	353	361	307	289	298	312	303	303	326	341	329	355	365	321
Ramnad	385	445	415	429	431	410	404	392	286	297	298	382	396	397	435	456	377
Tinnevelly	317	348	356	331	355	352	353	361	330	362	345	387	368	340	336	367	281
Malabar	861	868	880	859	880	882	871	898	884	881	877	877	879	877	869	892	865
South Kanara ..	585	595	596	593	596	582	581	580	579	581	575	577	583	588	588	587	576
Nilgiris	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	5
Total ..	10,467	11,648	11,097	11,280	11,286	10,517	10,870	11,322	10,842	10,930	11,019	11,263	11,678	11,538	11,534	11,704	11,056

APPENDIX D (I)

Explanations of vernacular terms used in the text.

Aman	or (winter paddy)—a term used in Bengal for the crop sown on low lands in March to May and harvested in December to January.
Aus	or (autumn paddy)—a term used in Bengal for early rice crop sown on high lands in April or May and harvested in August or September.
Boro	or (spring paddy)—a term used in Bengal for a crop sown in swamps in January or February and harvested in April or May.
Budama	a variety of dry rice grown in the uplands of Kistna and Godavari deltas.
Chakram	water-wheel used in 'cole' cultivation for lifting water.
Cole	a special method of rice cultivation in South Malabar.
Conjee	the decanted water after cooking rice.
Dalwa	The second short crop in the Telugu districts. The term is used to denote both the second-crop season and the varieties grown then.
Gathis	specially built granaries in Circars for storing paddy.
Gulla	a term used to denote a particular condition of looseness in the delta soils of Godavari.
Kaipad	the system of cultivation in the coastal lands in Malabar subject to sea inundation.
Kar	the short first crop in the Tamil districts. The term is used both for the season and for the varieties grown.
Kareim	a kind of water-lift made out of scooped out palmyra trunk used in the Kistna district.
Kharif	a term used in Bombay Presidency for the early monsoon crop.
Karinkora lands ..	low-lying lands in Malabar where water stagnates to a considerable depth during the monsoon season.
Kumeri	a system of primitive hill cultivation in South Kanara.
Kuruvai	the first *kar* crop of Tamil districts.
Lankas	the islands in the Godavari river.
Malayalee	a native of Malabar district.
Mammutty	an implement used for digging.
Modan lands	term used to denote the dry lands of Malabar usually sloping on the top and sides of hills dependent absolutely on south-west monsoon.
Parrah lands	are confined to coastal regions along the backwaters subject to submersion by tidal waters and excessive drainage from the higher parts of the delta.
Patta	a revenue term referring to the ownership of any piece of land.
Pattarais	temporary receptacles made out of straw ropes for storing paddy, common in Tanjore district.
Pattimannu	old village-site earth valued highly as manure in the Kistna delta.
Peddapanta	the main season (July to December) in the Circars.
Picottah	a common water-lift used for low lifts working on a see-saw principle.
Pishanam	the long-term second crop in the Tamil districts, synonymous with *samba*.
Podu	a system of primitive hill cultivation in Vizagapatam district.
Punam	a system of primitive hill cultivation in Malabar.
Punasa	the early season (March to June) in the Circars.
Puranas	sacred Hindu poetical works in Sanskrit
Puris	synonymous with pattarais.

Puttu	the Tamil name for glutinous rice.
Pyrugali	or corn winds which blow in Circars during the months of February to April.
Sake	a Japanese fermented spirit prepared out of rice.
Samba	the long second crop in Tamil districts, synonymous with Pishanam.
Sarva	the first long term, June to December, in the Telugu districts.
Seethe	the refuse waste in the preparation of indigo dye.
Settun	an implement—a sort of a mower used in Burma to cut the grass from rice fields before ploughing and puddling the soil.
Shemsu	a Chinese drink prepared out of broken rice.
Thandu thadupu ..	the system of keeping the fields continuously under puddle obtaining in portions of West Godavari district.
Udu	a particular system of cultivation in Tanjore where two varieties of rice, a short and a long are grown together mixed.
Uthiri kar	a special variety of paddy grown in parts of Tinnevelly and Chingleput districts.
Varam	a term applied to sharing the produce between the land-lord and the tenant.
Varinellu	a wild rice with long awns recognized as a weed in the rice fields of Malabar.
Vattuvari	or Vattam. The custom of deliberate mixing of different varieties of rice seed before sowing in Malabar.

APPENDIX D (II).

The common names of weeds and crop plants used in the text, with their botanical names.

Arai	Marsilia diandra.
Bengal gram	Cicer arietinum.
Black gram	Phaseolus mungo.
Castor	Ricinus communis.
Chillies	Capsicum annuum.
Cholam	Sorghum vulgare.
Cowgram	Vigna Catjang.
Cumbu	Pennisetum typhoideum.
Daincha	Sesbania aculeata var-cannabina.
Gingelly	Sesamum indicum.
Gogu	Hibiscus cannabinus.
Greengram	Phaseolus radiatus.
Groundnut	Arachis hypogaea.
Horsegram	Dolichos biflorus.
Indigo	Indigofera tinctoria and I-sumatrana
Kolingi	Tephrosia purpurea.
Korai	Cyperus rotundus.
Onion	Allium Cepa.
Pillipesara	Phaseolus trilobus.
Pungam	Pongamia glabra
Ragi	Eleusine coracana.
Redgram	Cajanus indicus.
Samai	Panicum miliare.
Senna	Cassia angustifolia.
Soyabean	Glycine hispida.
Sunnhemp	Crotalaria juncea.
Sweet potato	Ipomaea Batatas.
Tangedu	Cassia auriculata.

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